IMPACT OF RECREATION USE ON WATER QUALITY IN THE WHITE MOUNTAINS OF ARIZONA

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To

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Rocky Mountain Forest & Range Experiment Station

1973 Year Report

By

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ABSTRACT

Participation in water-based recreation activity has increased greatly within the last decade. In some areas use and development pressures have reached levels that have caused serious concerns among land managers regarding heavy use impacting on water recreation sites under their control. These concerns have led to the generation of a number of research efforts to determine the various effects of recreational use and development on water quality.

This report examines the water quality issue in relation to selected recreation lakes and streams in the White Mountains of Arizona. Four major parameters of water quality were investigated: (1) physical environmental factors, (2) chemical nutrient concentrations, (3) fecal bacterial contamination, and (4) visitor use effects.

Data were collected through field and laboratory analyses conducted over the 1973 summer recreation season.

Results presented in this report indicate intensive recreational use and development may be reflected by decreased water quality. For example, the research lake exhibiting the most intensive use and development showed significantly greater fecal bacterial contamination in the concentrated use area.

Management considerations developed in this report are directed toward assisting recreation land managers in recognizing and preventing present and future water quality problems.

SECTION 1

INTRODUCTION

Located in the east central region of Arizona, and along the eastern portion of the Mogollon Rim are the White Mountains; an area with a dramatic topography of volcanic origin, interspersed with timbered peaks, deep canyons and mountain grasslands. Elevations range from 5,000 to over 11,000 feet with precipitation accumulating to 50 inches per year on the higher peaks. Annual moisture and nautral springs supply water for the numerous lakes and streams in this mountain country. These waters, combined with a relatively cool summer climate, are particularly inviting to thousands of lower-desert residents that are, for the most part, no more than a half-day drive away.

Access to the White Mountains is provided by east-west highway State 73 and U. S. Highway 666 which runs north and south along the New Mexico boundary. Extensive back-road networks have developed over the years through logging, fire fighting and recreation activities making the most remote areas relatively available. Consequently, residents and visitors have much visual and physical access to the attractive natural landscape around them. Scenic overlooks, picnic areas, campgrounds, winter sports and fishing and hunting opportunities abound. The White Mountains supply satisfying recreation experiences for numerous visitors.

Large numbers of visitors frequenting the White Mountains during the summer recreation months have become an increasing land management concern. The general public is, as well, noticing growing recreational use pressures as evidenced by a recent newspaper headline entitled, "Popular Vacation Area Ready For Annual Crowd" (Quimby, 1974). The subject of this article is centered on recreation in the White Mountains with emphasis being placed on heavy visitation, "...all the places... will be too crowded as thousands of flatlanders from Phoenix and Tucson pour into the area for annual vacations" (p. 61).

Continued increases in visitor numbers in the future are highly probable. An even greater probability is that large increases in recreation use and development will be accompanied by increased competition and demand for recreation facilities resulting in damage to flora and fauna. Management practices and policies must be developed to anticipate and handle future load.

Problem Statement

Land managers recognize that water, in any aspect, acts as a "people magnet"; still or running, clear or turbid, cold or warm, water attracts people. Whatever its attraction or use and wherever located, water becomes a prime recreation resource.

In recent years participation in water-based recreation activities has increased to such an extent that major concerns among recreation land managers as to the possible negative impacts on water resources under their guardianship have developed. One concern centers on the decrease in water quality conditions that has been associated

with heavy or improper use of recreation waters and adjacent watersheds (Roseberry, 1964; Adams and Geiser, 1970).

Numerous summer homes, campgrounds, and day use sites (with related septic tanks, leech fields and pit privies) are located on the immediate watersheds of lakes and streams in the White Mountains. These areas are used extensively by many annual summer visitors. Associated significant questions that have been raised regarding these large numbers of people and facilities include: (1) Is water-based recreation contributing to the organic and chemical pollution of mountain recreation waters? and (2) Can there be guidelines of control established which would limit the possibility of present or future pollution associated with these water bodies? Examination of these important questions will contribute to the understanding of relationships between water-based recreational activity and water quality.

Various agencies charged with planning and protecting water-based recreation sites have encountered difficulties in the development and implementation of sound recreational water quality management plans. This is in part due to the inadequate amount of information that is currently available on specific water-based recreation sites around the country. Additional recreation water quality research data is needed.

Project Goals

Consideration of the problems described above prompted the development of a 1972 recreational water quality investigation in the White Mountains. That initial project had as its goal a preliminary assessment of several water quality conditions on selected lakes and

streams. This was accomplished by: (1) identifying light, moderate and intensive water-based recreation use sites; (2) determining valid and useful sampling techniques; (3) locating representative sampling stations to show possible recreation impacts on water quality; and (4) establishing a data base from which to make evaluations and future references.

Those sites chosen for the 1972 study (Figure 1) were the recreation waters of North Fork on the White River, Sheep's Crossing on the Little Colorado River, Cyclone Lake, Hawley Lake and Big Lake. Trout Creek was added to the selected research waters in 1973.

Final results of that initial research project, reported by Brickler and Lehman in early 1973, strongly indicated the need for a continuation of the 1972 study. This thesis represents the continuation of that initial project.

The goal for this 1973 research report is to show the results of continued water quality analysis and to determine possible effects of recreation activities and associated facilities on mountain lakes and streams. Further, the study will provide information that may assist land managers in the decision making processes regarding water-based recreation lands in the White Mountains.

Measurements for Project Goals

1. To replicate in the 1973 research project, water sampling sites and stations established in the preliminary water quality study of 1972.
    a. The lakes of the preliminary study were selected through identification of lightly, moderately and intensively used

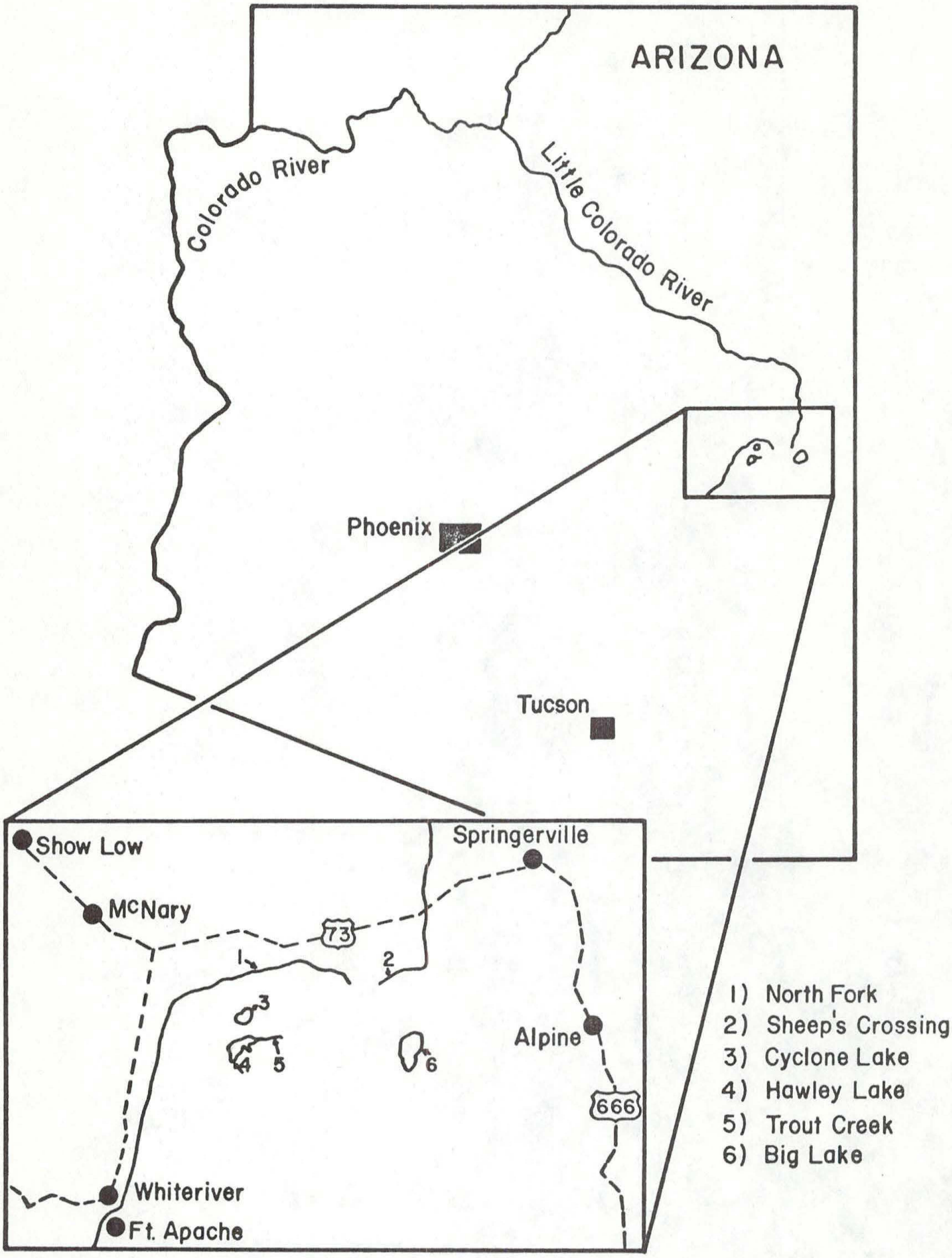


Figure 1. White Mountain study site locations in relation to state population centers and local communities.

water-based recreation areas which were Cyclone Lake, Big Lake and Hawley Lake, respectively. Sheep's Crossing received light to moderate use while North Fork was an intensively used recreation site.

b. Specific sampling stations were determined on the basis of possible drainage from homesite sewage systems and locations adjacent to campground facilities, picnic areas, boat docking and supply installations and general heavy recreational use areas.

c. Replication allows direct comparison and combination of the two sets of data which may show significant differences in the two separate studies.

2. To evaluate and make additions to the number of sampling stations determined in the 1972 study as indicated by the data results from that initial investigation. The locations of possible contaminant sources including pit privies, septic tanks, and inflow streams were also considered in the selection of new sampling stations.

3. To continue use of fecal coliform organisms as bacterial pollution indicators and add fecal streptococcus tests for the purpose of developing bacterial ratio analyses:

   a. Fecal bacteria species of the coliform group are derived from warm blooded animal excreta; their presence in water is indicative of an existing route of contamination to the sampled water source. These bacteria are recognized as pollution indicator organisms in Standard Methods for the Examination of Water and Waste Water (American Public Health Association, 1971).

b. The presence of fecal coliform bacteria does not indicate whether contamination is of human or some other warm-blooded animal origin. To aid in the differentiation between origins of the bacteria, a ratio of fecal coliform to fecal strepto-cocci organism numbers may be run. Should the ratio be four to one or greater, the probable origin is human. A fecal coli-form to fecal streptococci ratio of less than 0.7, indicates animal origin. Ratios between these values are typical of mix-tures of human and animal fecal coliforms.

4. To examine chemical and physical aspects of the waters including nitrate nitrogen and ortho-phosphate analyses, and measurements of water temperature, water depth, pH, turbidity and precipitation for the study sites.
5. To obtain visitor use data from each research site for the purpose of examining possible associations between water quality and visitor numbers.
6. To develop management guidelines of control designed to aid in the solution of observed water quality problems.

Delimitations

The data collection period for the 1973 project and that of the 1972 study began the first week of June and terminated in mid-August. This field period allowed intensive on-site research during both low and peak visitation occurring in the summer recreation season.

Visitor use data were obtained by making vehicle counts at each study site. These vehicle numbers were used as an index of visitor use.

This investigation was designed to identify possible effects of recreation on water quality during the summer use season. Field sampling did not extend beyond the three month period. Monitoring domestic water sources and systems in the recreation areas was not within the scope of this project.

SECTION 2

METHODS

Study Site Descriptions

The White Mountains were chosen for this research project because of their heavy recreational use and the fact that they contain a major segment of Arizona's surface water resources. The waters and immediate watersheds of Hawley Lake, Cyclone Lake and Big Lake were selected as study sites representative of three significant types and intensities of use. As separate stream research locations Trout Creek above Hawley Lake, Sheep's Crossing on the Little Colorado River and the North Fork of the White River at McCoy's Bridge served as typical recreational stream sites in the White Mountains.

Hawley Lake and Trout Creek

Hawley Lake, a 260 acre impoundment, and Trout Creek, main continuous inflow stream to Hawley Lake (Figure 2), are located on Fort Apache Indian Reservation at an elevation of 8,200 feet in Sections 19 and 24, T7N, R24E. Access to the area from Highway 73 is by paved road while the road system around the waters themselves is graded and graveled. Precipitation amounts to approximately 30 inches per year. Surrounding vegetation is of the coniferous forest type with open clearings of mountain grassland. Typical species include ponderosa pine (*Pinus ponderosa*), white fir (*Abies concolor*), mountain muhly (*Muhlanbergia montana*), and pine dropseed (*Blephaneuron tricholepis*). Soils in the

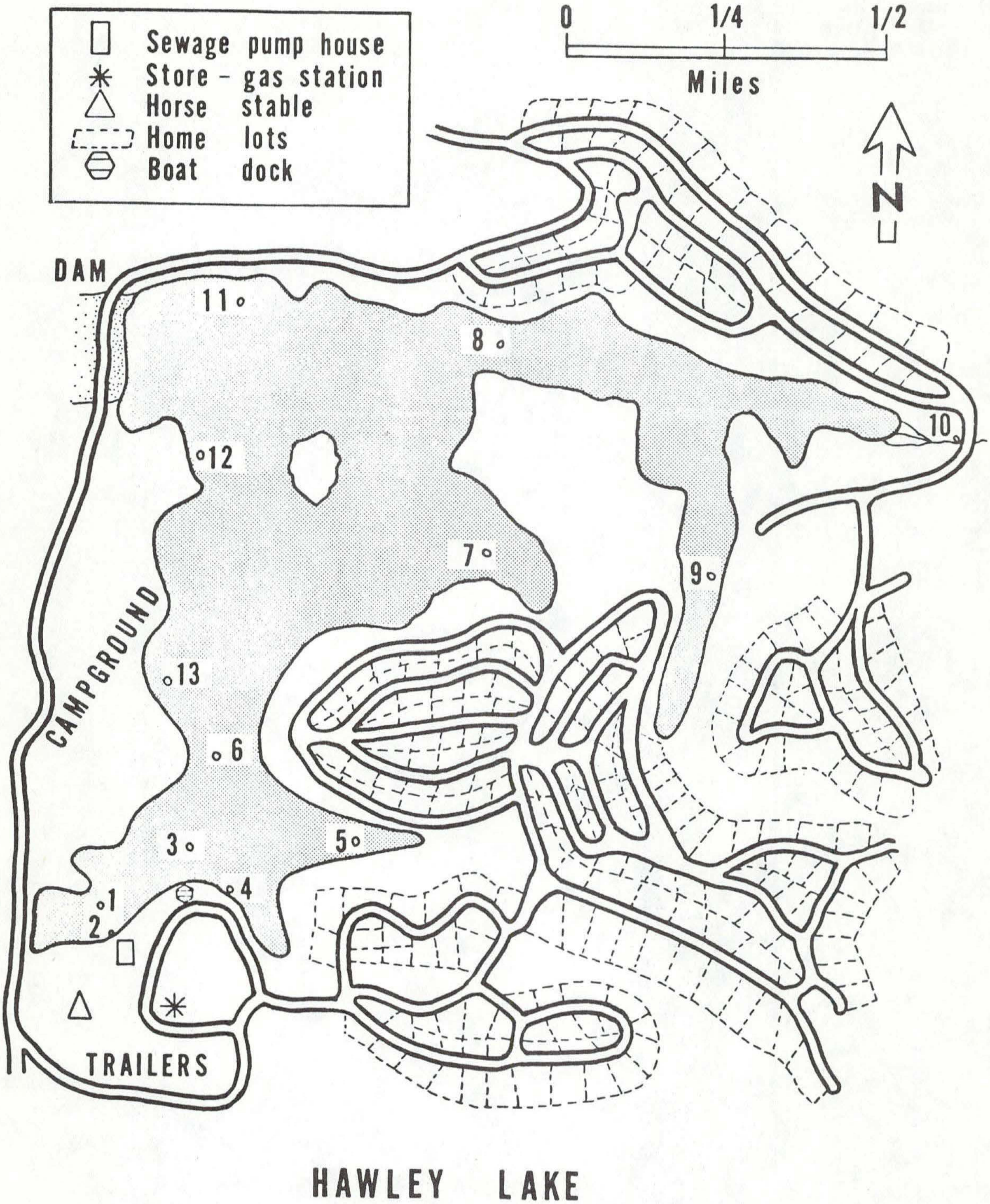


Figure 2. Water quality sampling Stations 1-13 and facility development at Hawley Lake recreation area: Station 10 is located on Trout Creek.

area are of the Sponseller-ESS series and the Gordo series (U. S. Department of Agriculture, 1968). The ESS series consists of well drained, medium and moderately fine textured soils formed in place from basic igneous rocks. Runoff is slow to rapid and erosion hazard moderate. Permeability is moderate averaging 0.63 to 2.0 inches per hour and depth to bedrock is generally 45 inches. The Gordo series is well drained with medium and moderately fine textured soils formed in alluvium from basalt, cinder and ash. Runoff is medium and erosion hazard is slight. This series is also of moderate permeability with a 38 inch average depth to bedrock. Main uses of both the Sponseller-ESS series and the Gordo series are for timber production, range, wildlife, recreation and water supply purposes.

Substantial development of the shoreline and adjacent watersheds has taken place at Hawley Lake and Trout Creek. This includes over 450 summer homes situated around one-half of the lake shoreline and on both sides of the stream watershed. Major forms of waste disposal at these homes are septic tank leech-field systems. Other developments present are rental cottages, a horse stable, boat dock facilities and a campground in addition to 25 to 30 pit privies, a small trailer park, a service station-store complex and one sewage pumphouse which services the store complex and the trailer park. Uses of the lake area consist of fishing, overnight camping, boating (gasoline motors prohibited), sightseeing, horseback riding and vacationing in summer homes. Swimming is prohibited at Hawley Lake as well as the other lakes investigated. Cattle grazing was not observed on the immediate watershed during either

the 1972 or 1973 periods, however, six head were sighted on the lake shoreline by Station 7 during a reconnaissance trip in June, 1974.

Sampling station locations could have been established by several methods. Random point selection or gridded station networks were two options. The other alternative was to locate stations which would sample both areas where the primary factor of concern was expected to occur and where it was unlikely to occur. In a project of this type random location of stations was not practical. Sampled sites were quite large and the main sampling factor, fecal coliform bacteria, was unlikely to be randomly distributed because fecal bacterial sources were not randomly located. For similar reasons the gridded method was undesirable. Fecal coliform bacteria of human origin would most probably have been in concentration near areas of heavy human use. Conversely, concentrations would be correspondingly low in areas of minimal human use. Therefore, a sampling station network designed to accomodate a recreational effect indicator system had to be developed to monitor both high and low use areas of the water bodies in order to accomplish the purpose of the project. Sampling stations for Hawley Lake and Trout Creek, and the other sites investigated, were established under this consideration.

Seven of the 13 sampling stations at the Hawley Lake recreation area were selected in 1972. These were numbers 1, 3, 5, 7, 8, 11, and 13 (see Figure 2). Those remaining were appended in 1973 to provide a better coverage for this intensively used site. Due to the expanded sampling program a divided sampling schedule was developed for Hawley Lake. The south half, Stations 1 through 7, was sampled on one sampling

day and the north half, numbers 8 through 13, including the Trout Creek station (10), would be sampled on the next consecutive sampling day.

Individual stations and associated developments and depths were:

Station 1) Located with stable to south and camping and fishing area on adjacent peninsula; depth--5.0 meters.

Station 2) Thirty-five meters down slope of sewage pumphouse installed to lift effluent into leech field out of immediate watershed; depth--0.2 meters.

Station 3) Directly off boat dock, a concentrated use facility; depth--7.0 meters.

Station 4) On shoreline 20 meters down slope from two heavily used pit privies; depth--0.2 meters.

Station 5) Mid-point in inlet with summer home development on immediate watershed; depth--4.5 meters.

Station 6) Deep chanel station, open water; depth--10.0 meters.

Station 7) Relatively isolated sampling station with limited development; depth--6.8 meters.

Station 8) Deep, mid-channel location with concentrated home development on north shore; depth--10.0 meters.

Station 9) Shallow inlet, summer homes on west shore. Earl Creek inflow point at south end; depth--3.5 meters.

Station 10) Station representing Trout Creek, main continuous inflow stream. Homes continue upstream 300 meters (data presented separately from Hawley Lake data); depth--0.1 meters.

Station 11) Open water in dam and entrance road area; depth--7.0 meters.

Station 12) Adjacent to campsites. Rocky, access inhibiting shoreline; depth--6.3 meters.

Station 13) Twenty-five meters offshore of center of camping activity; depth--3.1 meters.

Cyclone Lake

Cyclone Lake (Figure 3) has a surface area of 37 acres. It is one mile north of Hawley Lake in Section 8, T7N, R24E on Fort Apache Indian Reservation and, at 8,150 feet, has similar vegetation and soil types. Access is by a poorly maintained logging road. Use at this impoundment is restricted to low numbers of day users involved in the activities of fishing, boating (gasoline motors prohibited) picnicking and sightseeing. Construction development is virtually lacking at Cyclone Lake. The only structures are two pit privies 100 meters from the southeast shore. Six sampling stations selected in 1972 were continued in 1973 with no revisions or additions made. They were:

Station 1) Approximate to inflow point of Lame Deer Creek; depth--2.0 meters.

Station 2) Inflow point of Sand Creek; depth--2.0 meters.

Station 3) Deep, open water station representing center of lake; depth--10.1 meters.

Station 4) Deepest station, adjacent to dam outflow point; depth--14.0 meters.

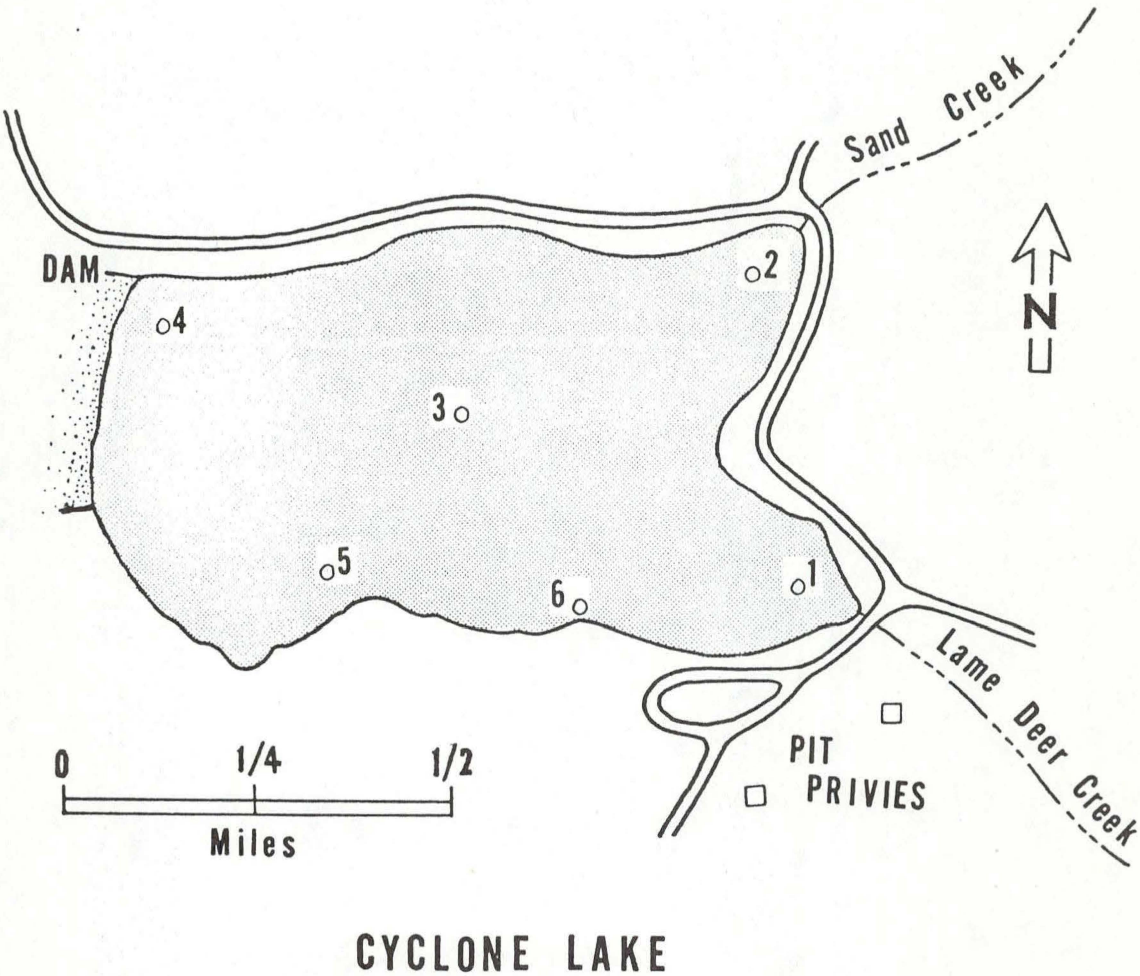


Figure 3. Water quality sampling Stations 1-6 and facility development at Cyclone Lake recreation area.

Station 5) Offshore of area with limited grazing activity; depth--6.1 meters.

Station 6) One meter offshore of small picnic site; depth--0.2 meters.

Big Lake

Big Lake (Figure 4), at an elevation of 9,000 feet and with a surface area of 540 acres, was the highest and largest water body sampled. This lake occupies portions of Sections 29, 30, 31 and 32, T6N, R28E on Apache National Forest. Access is by well maintained gravel road. Annual precipitation amounts to 40 to 45 inches. Associated vegetation is of the boreal forest and mountain grassland types. Among the dominant plant species are Engelmann spruce (Picea engelmannii), alpine fir (Abies lasiocarpa), Arizona fescue (Festuca arizonica) and various sedges (Carex spp.). Soils in the Big Lake area are of the previously described Gordo series. Development is less extensive and more dispersed than at Hawley Lake. Actual facilities consist of a boat dock, a store-service station complex, the concessionaire's private home, two large campgrounds with a combined number of 200 spaces, showers and flush toilets (installed in 1972 and 1973), a sewage stabilization pond located out of the immediate watershed, a public boat ramp and four sealed vault toilets. Area use includes grazing on portions of the north, east and west shores, fishing, boating (gasoline motors permitted) sightseeing and overnight camping.

The 7 sampling stations selected in 1972 were continued in 1973 and one station addition was made. The 8 stations were:

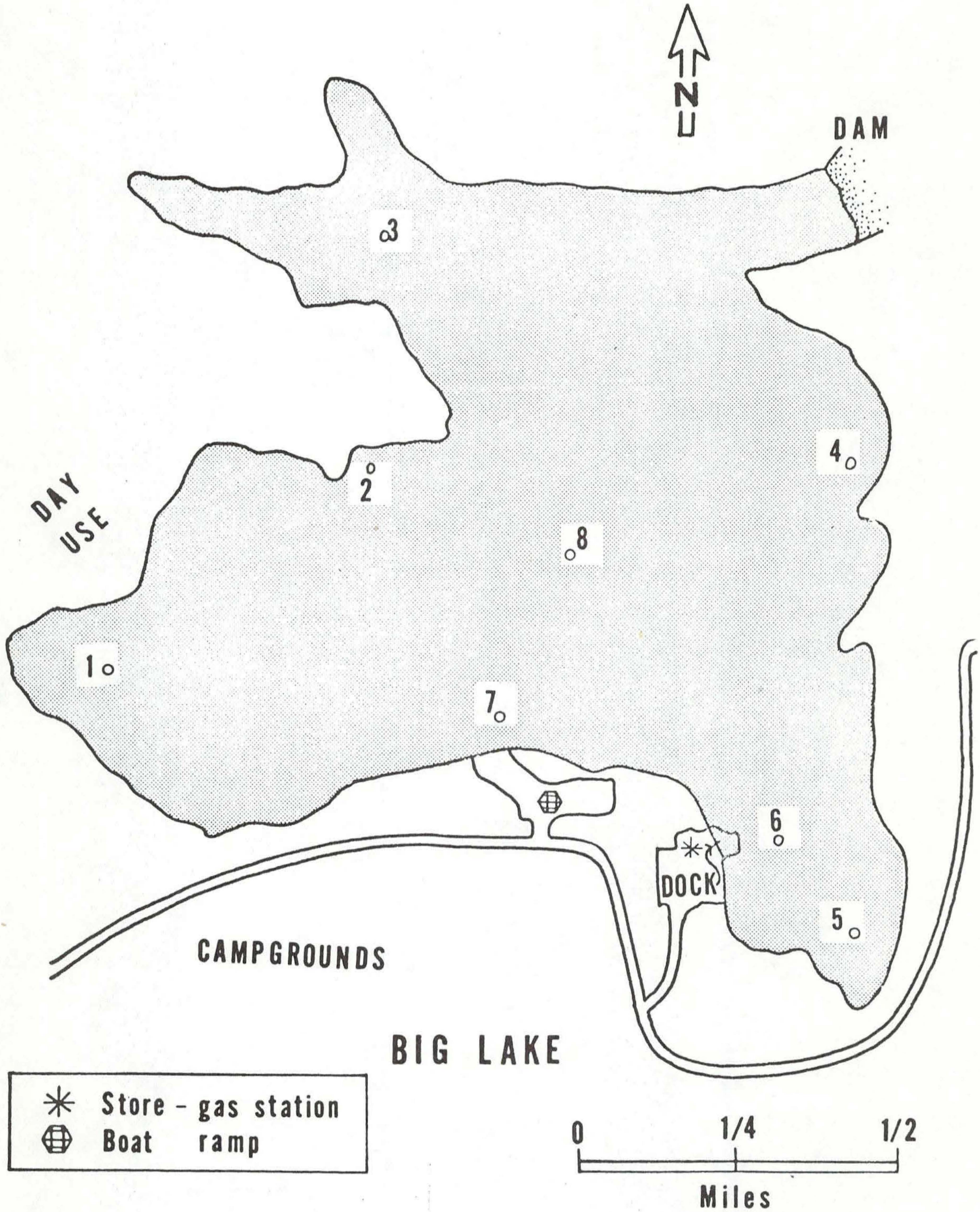


Figure 4. Water quality sampling Stations 1-8 and facility development at Big Lake recreation area.

Station 1) On western shore in area of limited day use; depth--8.3 meters.

Station 2) Near north shore. No camping or land vehicle access to this point; depth--7.1 meters.

Station 3) Representing northernmost section of lake; depth--8.1 meters.

Station 4) Fifteen meters offshore of most active grazing site; depth--8.0 meters.

Station 5) Established at inflow area of intermittent stream; depth--4.4 meters.

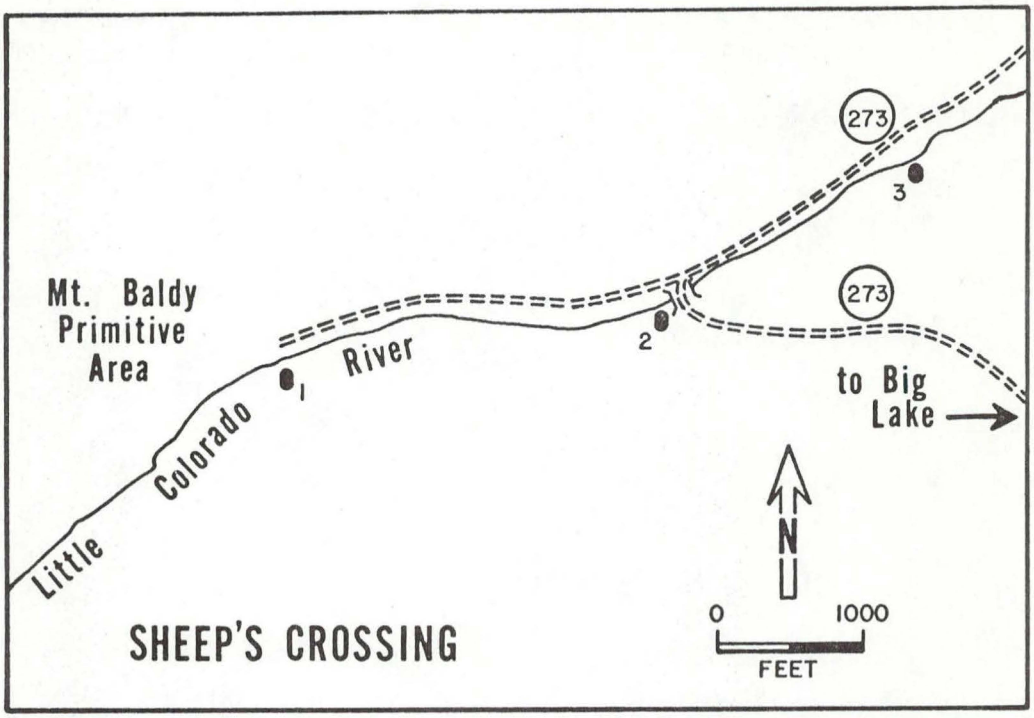
Station 6) Twenty-five meters off boat dock-store complex in open water; depth--6.1 meters.

Station 7) Offshore of public boat ramp and vehicle parking lot; depth--5.7 meters.

Station 8) Center and deepest lake station (added in 1973); depth--8.6 meters.

Sheep's Crossing

Sheep's Crossing (Figure 5) is a popular stream fishing site on the Little Colorado River, Apache National Forest (Sections 32 and 33, T7N, R27E). Precipitation, vegetation, soil types and elevation are comparable to the Big Lake area. Over-use by recreationists, with associated vegetation trampling and general denudation, caused the U. S. Forest Service to prohibit overnight camping and restrict vehicles to areas away from the stream bank beginning in summer, 1972. Use of the site now includes fishing, hiking, sightseeing, picnicking and limited



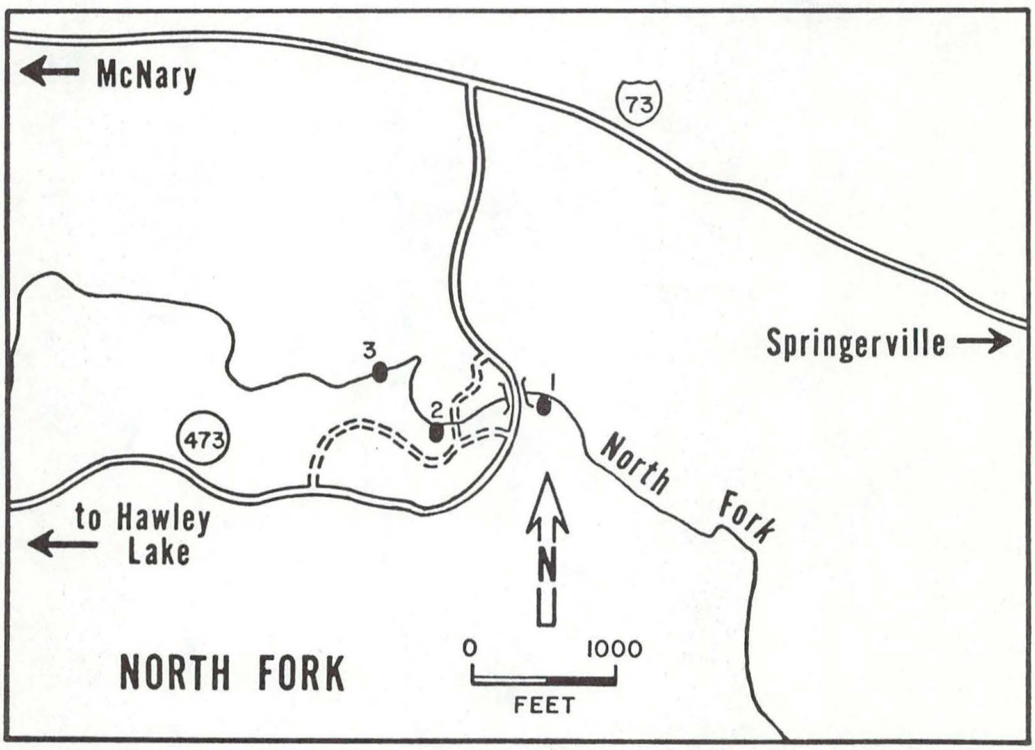


Figure 5. Water quality sampling Stations 1-3 and developments at Sheep's Crossing and North Fork recreation areas.

grazing. Three water sampling stations were selected for this site in 1972 and maintained in 1973. Their locations were established to monitor water quality status upstream, at mid-point and downstream from the center of recreational activity. Station 1 was situated adjacent to the Mount Baldy Primitive Area boundary fence one-third mile upstream of the bridge crossing. Station 2 was placed 5 meters upstream from the bridge and Station 3 one-quarter mile downstream.

North Fork

The research site on the North Fork of the White River (Figure 5) was located at McCoy's Bridge (Section 31, T8N, R25E) on Fort Apache Indian Reservation. This reach of stream is 3-1/2 miles north of Hawley Lake at an elevation of 7,760 feet. Vegetation and soil types, here, are similar to those of Hawley Lake. This site has long been a favorite camping and fishing location for summer recreationists. Topography limits usable campsite area to 1-1/2 to 2 acres of relatively level ground along 150 meters of the stream below McCoy's Bridge. Generally, there are 5 to 15 separate camps in this small area throughout the summer recreation season. There are no developed campsites. Waste disposal facilities consist of two pit privies, both on the north side of the stream. Sampling stations were selected in the same manner as those at Sheep's Crossing but with shorter distances of separation due to the smaller site. Station 1 was established 150 yards upstream of the camping area; Station 2 adjacent to the area; and Station 3, 150 meters below.

Field Procedures

A water sample collection program was developed to insure each water body would be sampled at the same time each sampling day throughout the summer recreation season to reduce the number of variables which tend to interfere with development of an indicator organism monitoring system of this type. All samples were collected between 8:00 a.m. and noon each sampling day. In addition, the sampling procedure for each water body was designed to allow sample collection, transport and bacterial processing to be completed in less than 8 hours as suggested by the American Public Health Association (1971).

Water samples were taken with sterilized biological oxygen demand (BOD) bottles. These have ground glass stoppers and were protected against contamination with sterilized foil wrapping placed over the tops. For surface samples a slow scooping technique (Kittrell, 1969) was employed. Removed stoppers were kept in foil to prevent contact with any contaminated objects. After filling, a small amount of water was poured from the bottles leaving an air space for subsequent shaking in the laboratory. Where depths permitted, stratified samples were collected at 2 meter, 4 meter and bottom intervals for each station. This was accomplished through the use of a tri-flushing BOD sampler. With individual bottles secured inside, the BOD sampler was lowered over the side of a small boat to the desired depth by means of a line graduated in meters.[1] After air bubbles, emanating from the sample, were no

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1. It is necessary in stratified sampling to collect from the surface downward due to disturbance of upper stratifications by the sampler and, in this case, by bubbles which are products of the flushing process.

longer visible on the surface the sampler was brought up. Its threaded lid was removed and the BOD bottle extracted. Then the same pouring procedure followed, as was used on surface samples. All water samples were placed on ice inside an insulated container for transportation to the laboratory.

Water temperatures were obtained with a standard centigrade thermometer and registered in a field log. For stratified temperatures the Meyer method (Schwoerbel, 1970) was used with the 300 to 600 millilitres of water remaining in the sampler after bottle extraction. In all cases the thermometer bulb was left submerged during temperature readings. Due to the shallowness of the stream sites in this investigation only surface samples and temperatures were taken.

After collection of all required samples at a lake station, a Secchi disc reading was made as a measure of relative turbidity and registered in the field log. This disc is 25 centimeters in diameter with 4 equal sections formed by 2 perpendicular lines bisecting the upper surface. These sections are painted to alternate black and white. The Secchi disc is attached to a line marked off at one meter intervals and is allowed to sink slowly until it just disappears. The depth at which this takes place is the depth of transparency or the turbidity measurement.

Official weather stations at Hawley Lake and Burro Mountain (near Big Lake) were the sources of precipitation data for this study. These stations are maintained by the White Mountain Apache Tribe and the U. S. Forest Service, respectively.

Automobile counts were made each sampling day and used as an index of visitation. On the average, 3.2 individuals occupied each automobile in the recreation areas (Armstrong, 1974). The great number of possible vehicle locations prohibited complete counts from being conducted at the Hawley Lake-Trout Creek area and Big Lake. Campground automobile counts represent visitor use at these sites. Use data for Cyclone Lake, Sheep's Crossing and North Fork include all vehicles present at the individual sites during each sampling day.

Laboratory Procedures

Laboratory space for the investigation was provided by the U. S. Fish and Wildlife Service. Actual location of the facility was Alchesay-Williams Creek National Fish Hatchery, Fort Apache Indian Reservation. This location was convenient to all study sites.

Bacteriological analysis of water samples included tests for both fecal coliform and fecal streptococci bacteria. A membrane filter technique, developed by the Millipore Corporation and described by the American Public Health Association (1971) was employed in combination with m FC agar and m Enterococcus agar. These two agar types were prepared and dispensed into culture plates and then refrigerated the evening before use. Fecal streptococci agar plates were cultured on alternate sampling days due to a 48 hour incubation requirement and limited incubator capacity.

Upon return from the field all samples were left in ice until processed for incubation. Fecal coliform culture plates were sealed in plastic and submerged in a water bath for 24 hours at 44.5°C. Fecal

streptococci plates remained in a dry incubator for 48 hours at 35°C. Fully incubated cultures were removed from the incubators and indicator organisms counted using a 10X microscope. Results were recorded in a laboratory log as numbers of bacteria colonies per 100 millilitres of sample. On a number of occasions throughout the summer sampling season cultures exhibiting typical characteristics of recorded indicator organisms were delivered to the Department of Microbiology, The University of Arizona to confirm the researcher's bacteriological techniques. In addition, cultures exhibiting atypical, or unusual, colony growth were sent to the department for identification. The resulting species list from these latter tests is in Section 3.

Colorimetry was selected as the analytical method to be used for chemical determinations. A Hach DR-EL engineer's laboratory was obtained for that purpose. Reagents for selected tests were supplied with the portable laboratory. Specific reagents were added to samples to form compounds with definite color characteristics and in amounts directly proportional to the concentration of the substance being measured. Main component of the laboratory is a photoelectric colorimeter which employs a photoelectric cell as the sending element. An ordinary light bulb acts as a light source and monochromatic light is obtained through use of various filters. This monochromatic light is directed through a cell containing the sample and light penetrating the sample hits the photoelectric cell. Current developed by the photoelectric cell is translated into percent transmission through a galvanometer. Matched meter scales and filters are used for each chemical test. Basic procedures for obtaining the nitrate nitrogen, ortho-phosphate and pH

data followed those outlined in Hach Chemical Corporation's Methods Manual (1971). Cadmium reduction was the specific procedure utilized in nitrate nitrogen determinations. Samples for this and other chemical tests were taken from unused water remaining in BOD bottles after bacterial samples had been decanted. Ortho-phosphate readings were obtained through the Stannaver method and a wide range indicator procedure was utilized in pH determinations.

Statistical Applications

Statistical analyses of collected data were based upon tests of significance including bivariate correlation and the Student's t-test. These tests are calculations by which sample results are used to throw light on the truth or falsity of a null hypothesis (Snedecor and Cochran, 1967). A test criterion is computed measuring the extent to which a sample departs from a null hypothesis in some relevant aspect. Should the value of a test criterion fall beyond certain limits into a "critical region," the departure is said to be statistically significant. Typical values for chosen significance levels are 0.05 and 0.01 (Blalock, 1972). The specific value of the significance level is based on both the seriousness of a type I error, which is rejecting a null hypothesis when it is true, as opposed to a type II error, which is accepting a null hypothesis when it is false (Steel and Torrie, 1960). A significance level is exactly the probability of rejecting a null when it is true. The significance level, or critical region, of 0.05 was selected for this project.

Student's t-test

A t-test determines whether the difference of 2 sample means is significant. It is highly probable that 2 samples from the same population would be different due to natural variability in the population, therefore, it is clear that a difference in sample means does not necessarily imply a difference in populations. The goal of this type of statistical analysis is to establish whether or not a difference between 2 samples is significant. Significance does not mean important or of consequence; it is used to mean indicative of or signifying a true difference between the 2 populations being compared (Nie, Bent and Hull, 1973).

If 2 populations being compared have equal variances Student's t statistic follows the equation:

$$t = (\bar{X}_1 - \bar{X}_2)/\mathrm{SQRT}\ (V/N_1 + V/N_2)$$

where; $\bar{X}_1$ and $\bar{X}_2$ are the group means, SQRT signifies square root, V is the pooled variance and N_1 and N_2 are group counts. t is interpreted with degrees of freedom (df) of $N_1 + N_2 - 2$. With unequal population variances an approximation to Student's t statistic is computed:

$$t' = (\bar{X}_1 - \bar{X}_2)/\mathrm{SQRT}\ (V_1/N_1 + V_2/N_2)$$

where; V_1 and V_2 are group variances. The probability of this t' is approximated by interpreting it as t, but with degrees of freedom:

$$df = \frac{(V_1/N_1 + V_2/N_2)^2}{\dfrac{(V_1/N_1)^2}{(N_1 - 1)} + \dfrac{(V_2/N_2)^2}{(N_2 - 1)}}$$

To determine whether the 2 populations have equal variances an F test may be performed. F is computed through division of the larger variance by the smaller variance.

Bivariate Correlation

Bivariate, or simple, correlation was used as a measure of the degree to which variables varied together, or a measure of their intensity of association. The correlation coefficient (r) is an unbiased estimate of the corresponding population correlation coefficient (Blalock, 1972). Unlike a variance or a regression coefficient the correlation coefficient is independent of units of measure; it is an absolute or dimensionless quantity. Where linear correlation is small, r is near zero. With high linear correlation r is near +1 or -1. In this case a unit change in one variable implies approximately a unit change in the other. The bivariate correlation coefficient is defined by:

$$r = \frac{\text{Sum}_{i=1}^{N} (X_i - \bar{X})(Y_i - \bar{Y})}{\text{SQRT}\ \{[\text{Sum}_{i=1}^{N} (X_i - \bar{X})^2][\text{Sum}_{i=1}^{N} (Y_1 - \bar{Y})^2]\}}$$

where; X_i is the ith observation of variable X, Y_i is the ith observation of variable Y, N is the number of observations, and $\bar{X}$ and $\bar{Y}$ are the means of variables X and Y.

Computer formats were developed using the SPSS, or Statistical Package for the Social Sciences (Nie, Bent and Hull, 1970), program systems manual which was incorporated into both the t-test and correlation analyses. This was a means of facilitating more rapid data compilation and computation. All statistical results were obtained through the use of SPSS formats.

SECTION 3

DATA PRESENTATION

Field and laboratory data from the 1973 summer research season are presented in this chapter. Graphical and textual material exhibit the separate results of: chemical tests including pH, nitrate nitrogen and ortho-phosphate information; the physical determinations of turbidity, precipitation and water temperature; microbiological analyses for fecal coliform and fecal streptococci bacteria; and visitor use counts.

pH

The abbreviation pH represents potentia hydrogenii and indicates strength or concentration of hydrogen ions. This variable was measured for each individual water body on 5 separate occasions. pH determinations (Table 1) fell between 7.0 and 8.0 indicating neutral to slightly basic water environments. Basic conditions of this kind are common to natural waters and caused by surrounding soil characteristics and decomposition and respiration processes which bring carbonate into solution as calcium carbonate (Machenthun and Ingram, 1964).

Nutrients

Phosphorus is one of the major elements regarding biological productivity in any region of the world. Only the inorganic, orthophosphates ($H_2PO_4^-$, $HPO_4^=$, and $PO_4^=$) and various undifferentiated organic phosphates are important in limnology. Most relatively

Table 1. Mean and extreme pH determinations from the separate water bodies during 1973 summer sampling period.

Study Sites	pH		
	Mean	Maximum	Minimum
Big Lake	7.7	8.0	7.4
Cyclone Lake	7.5	7.8	7.3
Hawley Lake	7.5	8.0	7.0
North Fork	7.5	7.8	7.2
Trout Creek	7.4	7.9	7.2
Sheep's Crossing	7.4	7.9	7.0

uncontaminated lake districts have surface waters containing 0.01 to 0.03 ppm phosphorus but in some waters, not obviously polluted, much higher values appear to be normal. Soluble phosphate usually amounts to 10 percent of the phosphorus present. The total quantity of phosphorus in a lake or stream depends largely on geochemical and influent characteristics (Hutchinson, 1957).

A second nutrient basic to productivity is nitrogen. Three main sources of nitrogen compounds in a water body are influents, precipitation on the water surface and fixation in the water and in sediments. Inorganic ammonia compounds are major nitrogenous end products of bacterial decomposition of organic matter including human and animal wastes. Bacterial nitrifiers readily oxidize ammonia to nitrite and then nitrate according to the general reactions of Table 2. Nitrates then serve to fertilize lake and stream waters. Concentrations of inorganic compounds of nitrogen seldom exceed a few ppm in surface waters, although they may reach levels of 100 ppm in ground waters where they are not subject to biological uptake (Water Quality Division Committee on Nutrients in Water, 1970).

Both nitrates and phosphates are primary nutrient constituents of sewage effluents. Intensive use of a recreation area could put demands on waste facilities beyond their capacities (be they earthen pit privies or tertiary treatment installations) the effect of which might be evidenced by increased amounts of nutrients in adjacent water bodies. Nitrate nitrogen and ortho-phosphate concentrations were monitored to determine if such a problem might exist in the waters selected for this investigation.

Table 2. Nitrification process showing chemical reactions and bacteria associated with oxidation of ammonia and nitrite to the basic fertilizing agent, nitrate.

Oxidizing Bacteria	Nitrification Process
Nitrosomonas spp.	$2NH_3^+ + 3O_2 \underline{\text{ Bacteria }} = 2NO_2^- + 2H^+ + 2H_2O$
Nitrobacter spp.	$2NO_2^- + O_2 \underline{\text{ Bacteria }} = 2NO_3^-$

Nutrient information gained through Hach colorimetry tests showed the water bodies to be enriched. Of the three lakes studied, Big Lake (Figure 6) and Cyclone Lake (Figure 7) displayed more gradual changes in nutrient concentrations during the sampling period. Determinations for Hawley Lake were more erratic as shown by Figure 8. Although nutrient test result patterns varied between the lakes, ranges of overall mean results were relatively similar. Mean nitrate nitrogen readings fell between 2.2 and 3.8 ppm while ortho-phosphate data ranged from 0.02 to 0.18 ppm; Hawley Lake having the widest spread in both categories. Several nutrient illustrations appear to be lacking a final ortho-phosphate data point. This was due to accidental contamination of the reagent supply necessary for detection of that particular nutrient.

Stream data were somewhat more variable. Trout Creek (Figure 9) displayed ortho-phosphate and nitrate nitrogen ranges approximately double those of Hawley Lake. However, the greatest concentration of nitrate nitrogen detected during the research project was 6.8 ppm recorded at North Fork (Figure 10) the second week of July. Ortho-phosphate results for this stream were correspondingly high, the maximum reading being 0.21 ppm. Sheep's Crossing supplied the least varying nutrient information (Figure 11) of the stream reaches. Ortho-phosphate data for Sheep's Crossing were well within the lower range identified for the three lakes. Nitrate nitrogen results averaged between 2.8 and 4.4 ppm, slightly higher than the upper end of the lake nutrient range.

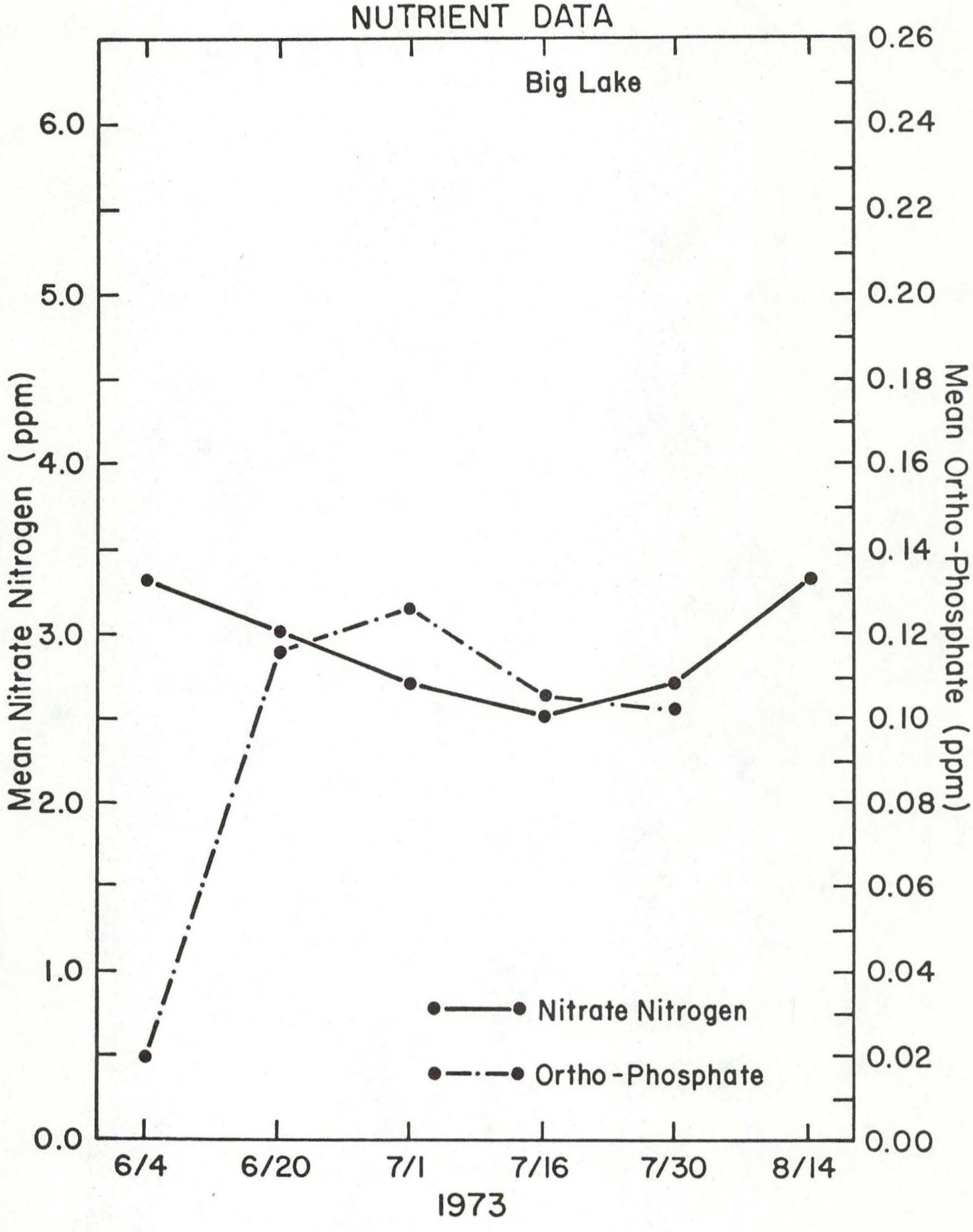

Figure 6. Mean concentrations of nitrate nitrogen and ortho-phosphate per sampling date at Big Lake, 1973.

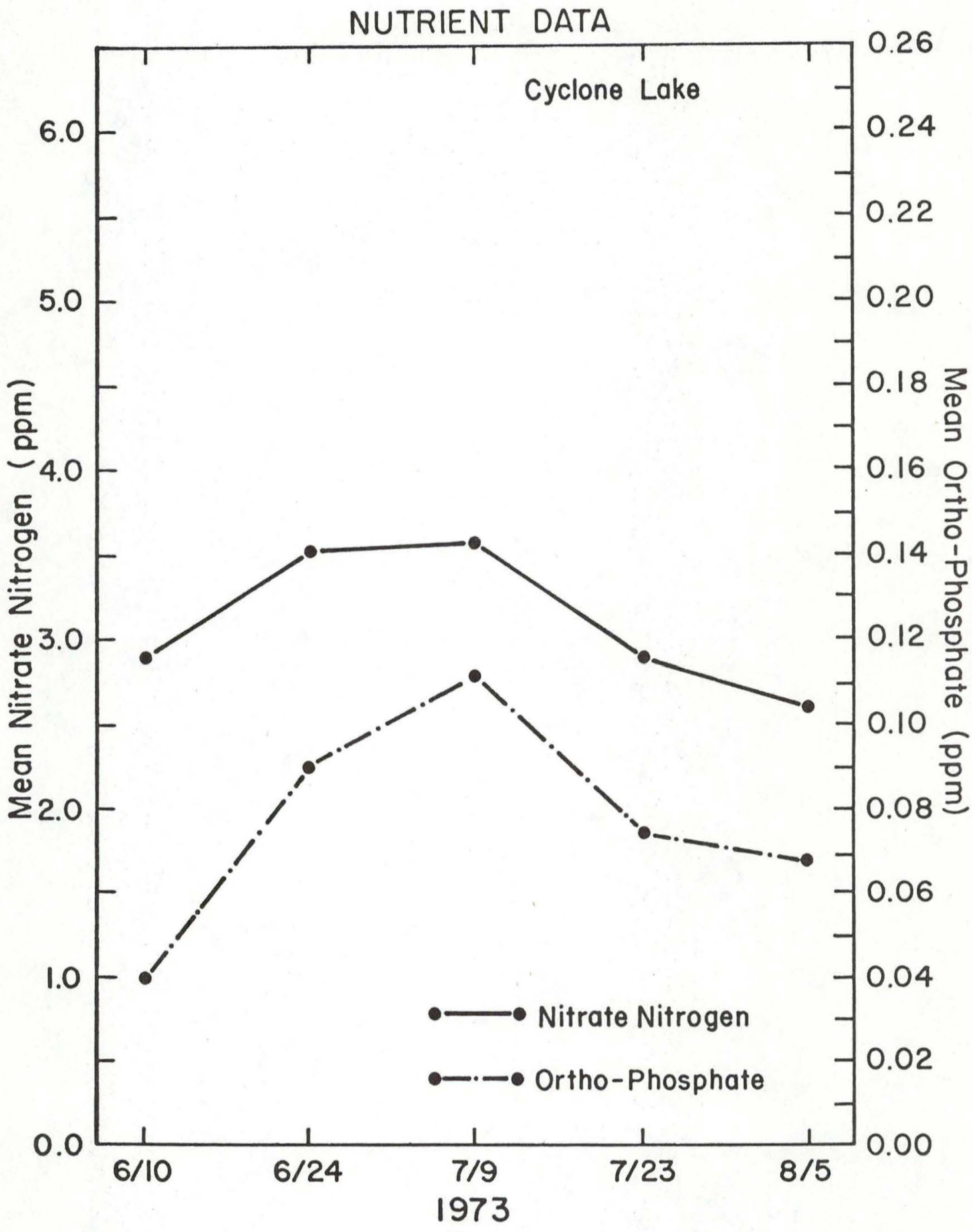

Figure 7. Mean concentrations of nitrate nitrogen and ortho-phosphate per sampling date at Cyclone Lake, 1973.

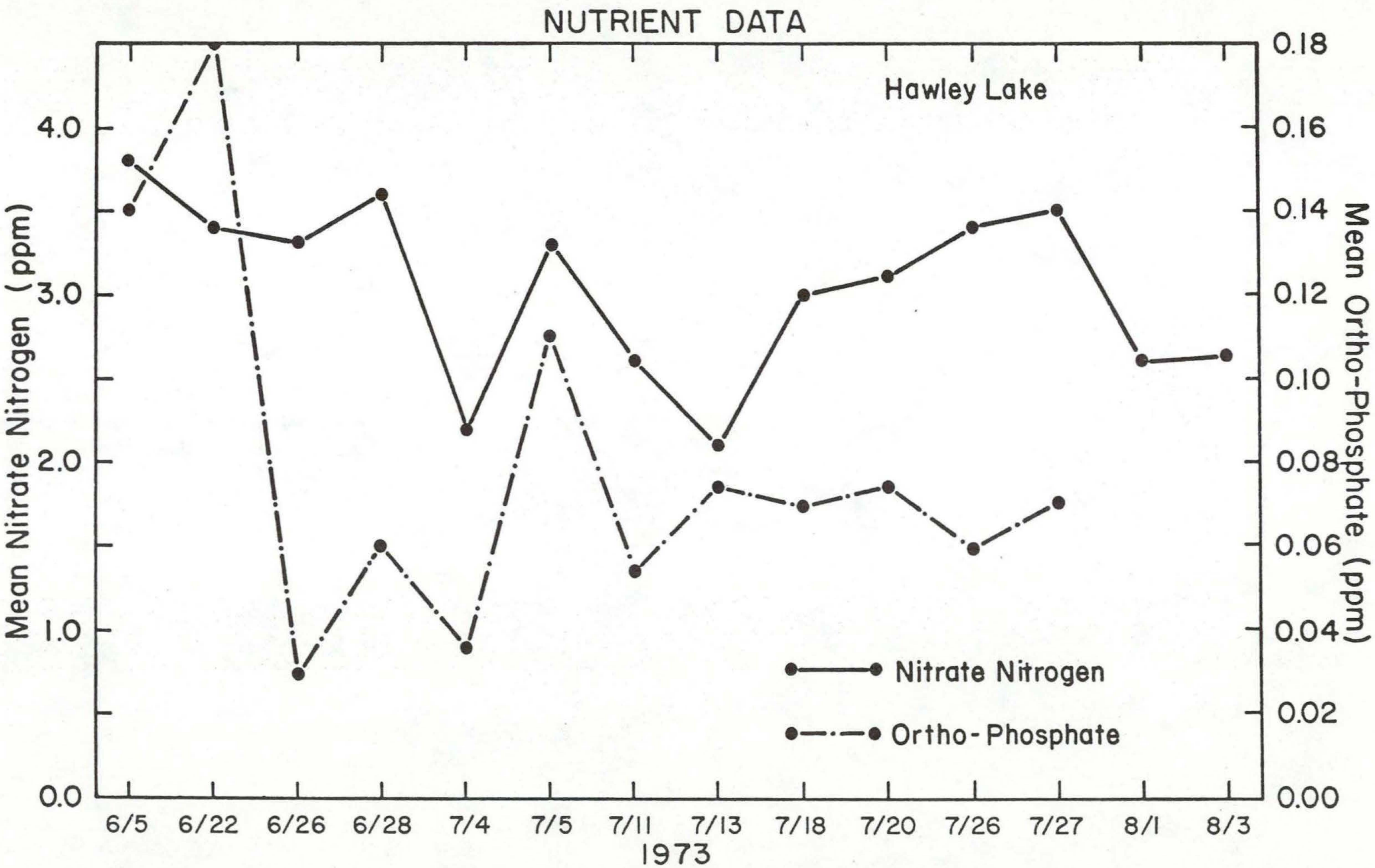

Figure 8. Mean concentrations of nitrate nitrogen and ortho-phosphate per sampling date at Hawley Lake, 1973.

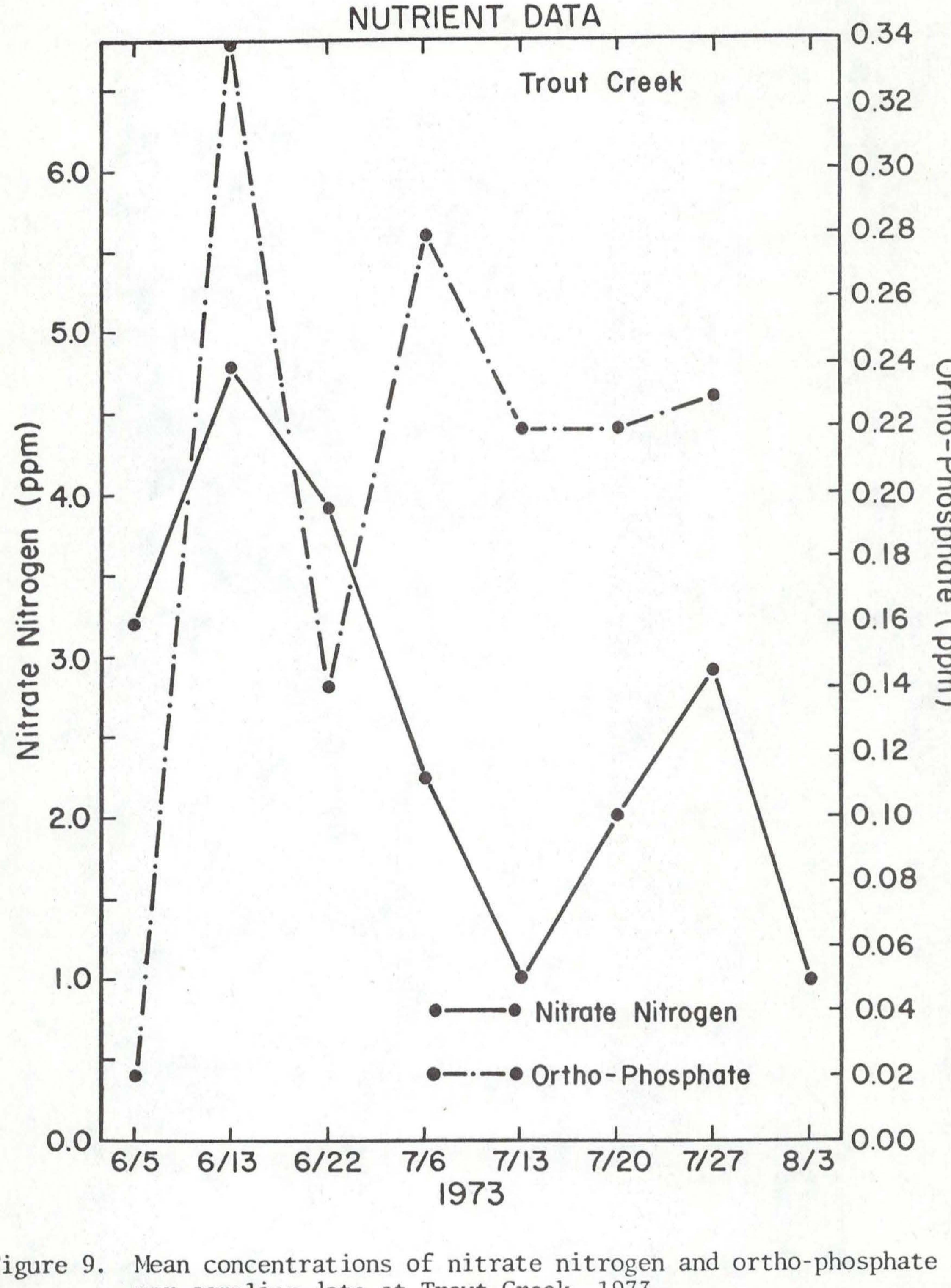

Figure 9. Mean concentrations of nitrate nitrogen and ortho-phosphate per sampling date at Trout Creek, 1973.

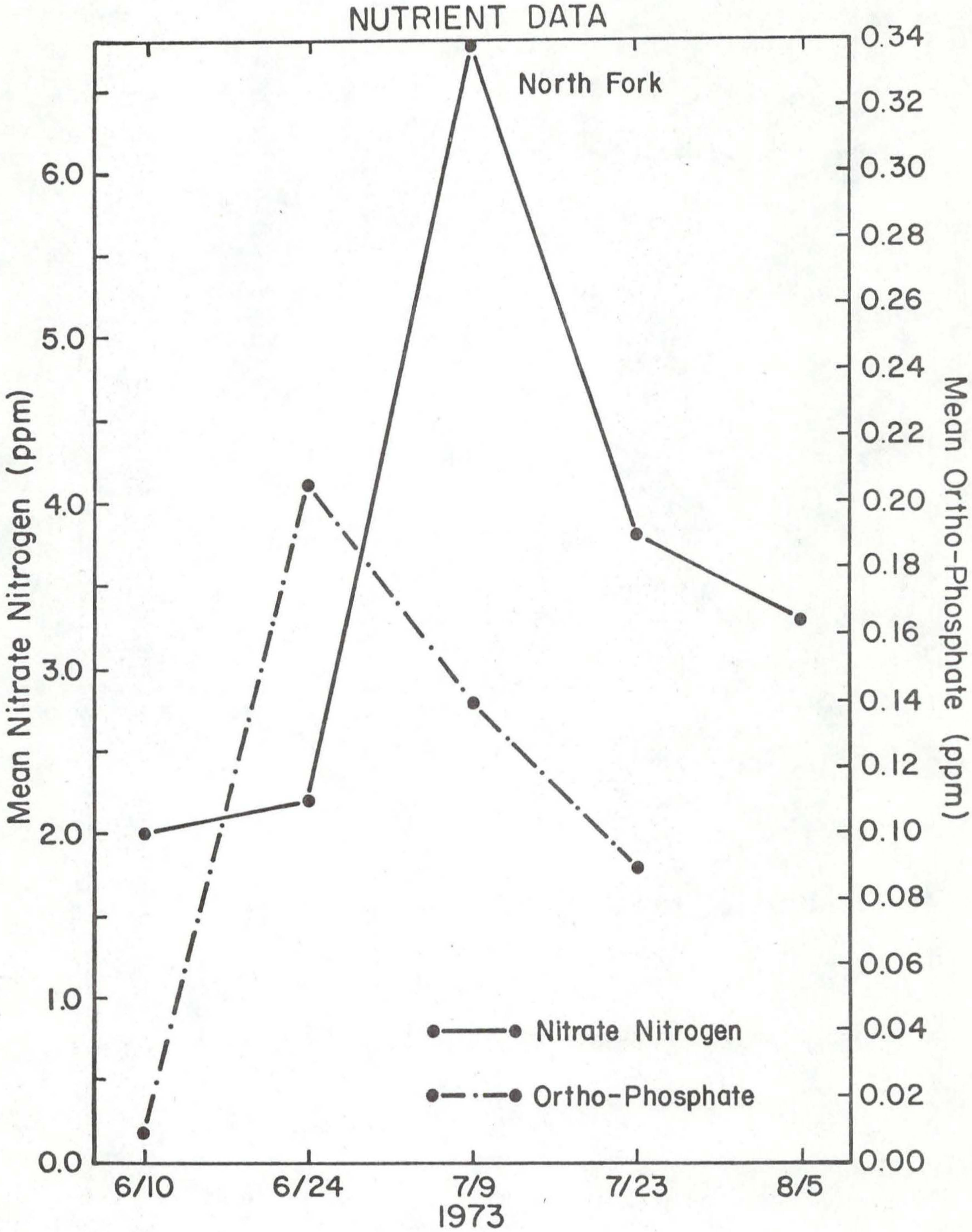

Figure 10. Mean concentrations of nitrate nitrogen and ortho-phosphate per sampling date at North Fork, 1973.

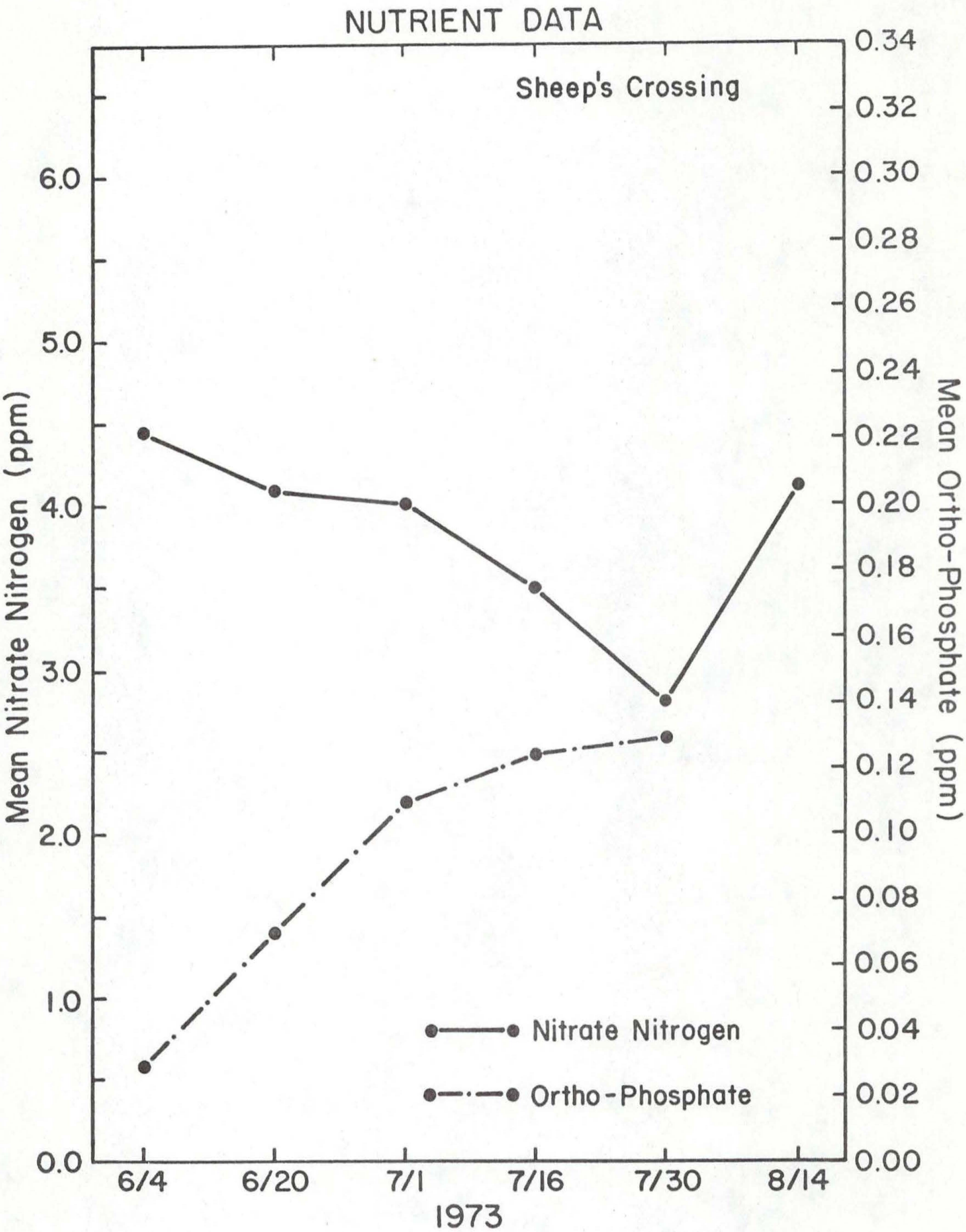

Figure 11. Mean concentrations of nitrate nitrogen and ortho-phosphate per sampling date at Sheep's Crossing, 1973.

Precipitation

Precipitation data were collected for this research project during June, July and August, 1973. Of primary concern was increased rainfall's effect on bacteria counts as described by Geldreich et al., (1968). Two official weather stations supplied information used in this investigation. Burro Mountain Station, Apache National Forest, served as the data source for Big Lake and Sheep's Crossing. Rainfall registered at the Hawley Lake Station was applied to Hawley Lake, Trout Creek, Cyclone Lake and North Fork.

Rainfall data from Burro Mountain Weather Station (Figures 12 through 14) show June having 3 days of measurable precipitation. Total accumulation was 1.30 inches. July registered the most precipitation with 16 days of rainfall amounting to 5.66 inches. August 1st through the 15th, termination date for field research, recorded a total of 1.54 inches rainfall. Accumulation for the entire month equaled 3.65 inches.

Information obtained from Hawley Lake Weather Station records (Figures 12 through 14) presented a precipitation pattern quite similar to that of Burro Mountain. June received least rainfall of the summer period with 6 measurable days totaling 1.97 inches. Seventeen days in July accumulated 5.05 inches of rain. A majority of that precipitation (4.01 inches) was received between the 11th and the 18th of July. Seven of the first 15 days of August accumulated 1.11 inches of precipitation. Total rainfall recorded for August was 2.9 inches.

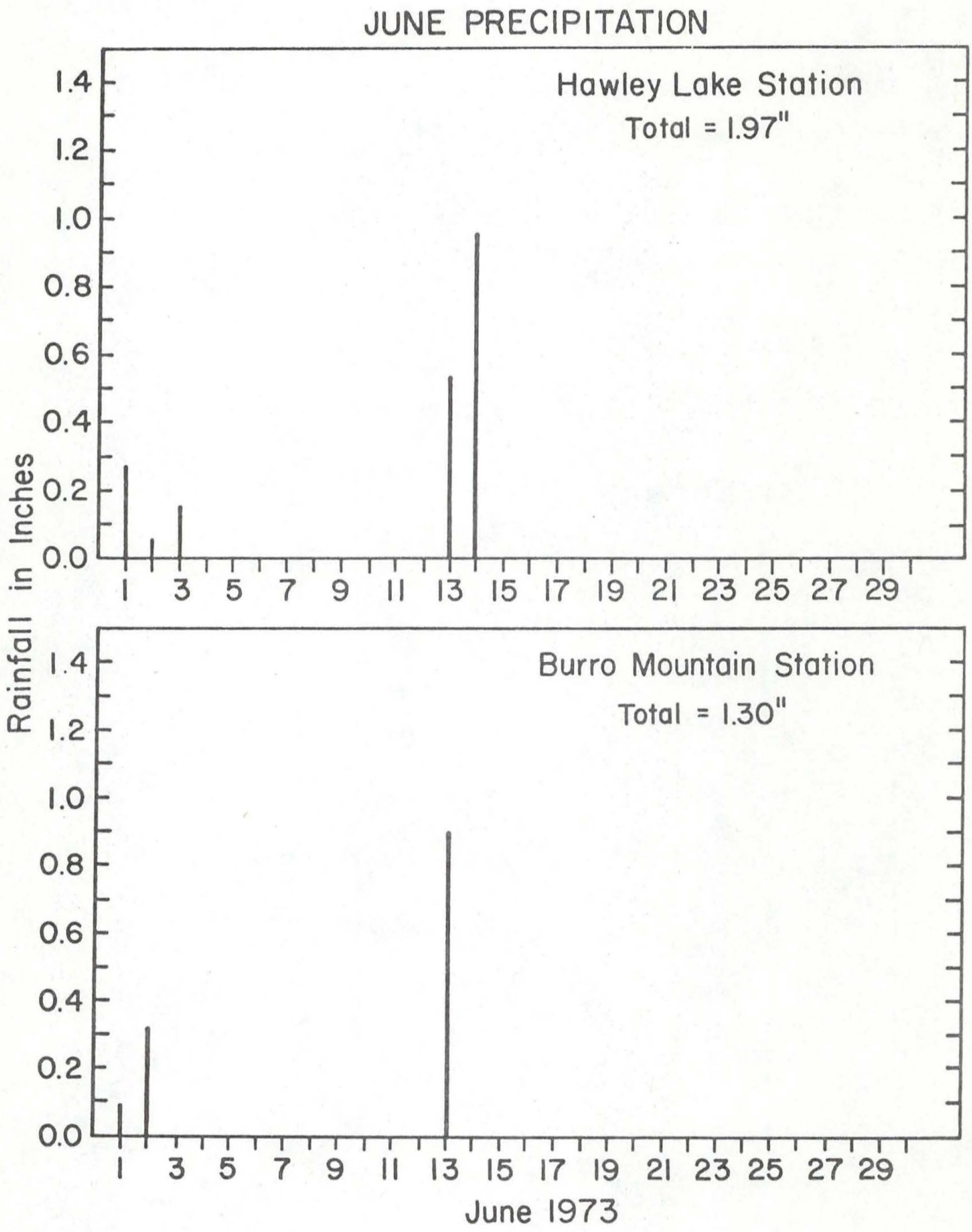

Figure 12. Precipitation events and accumulations for June, 1973: Hawley Lake Station represents Hawley Lake, Trout Creek, Cyclone Lake and North Fork; Burro Mountain Station represents Big Lake and Sheep's Crossing.

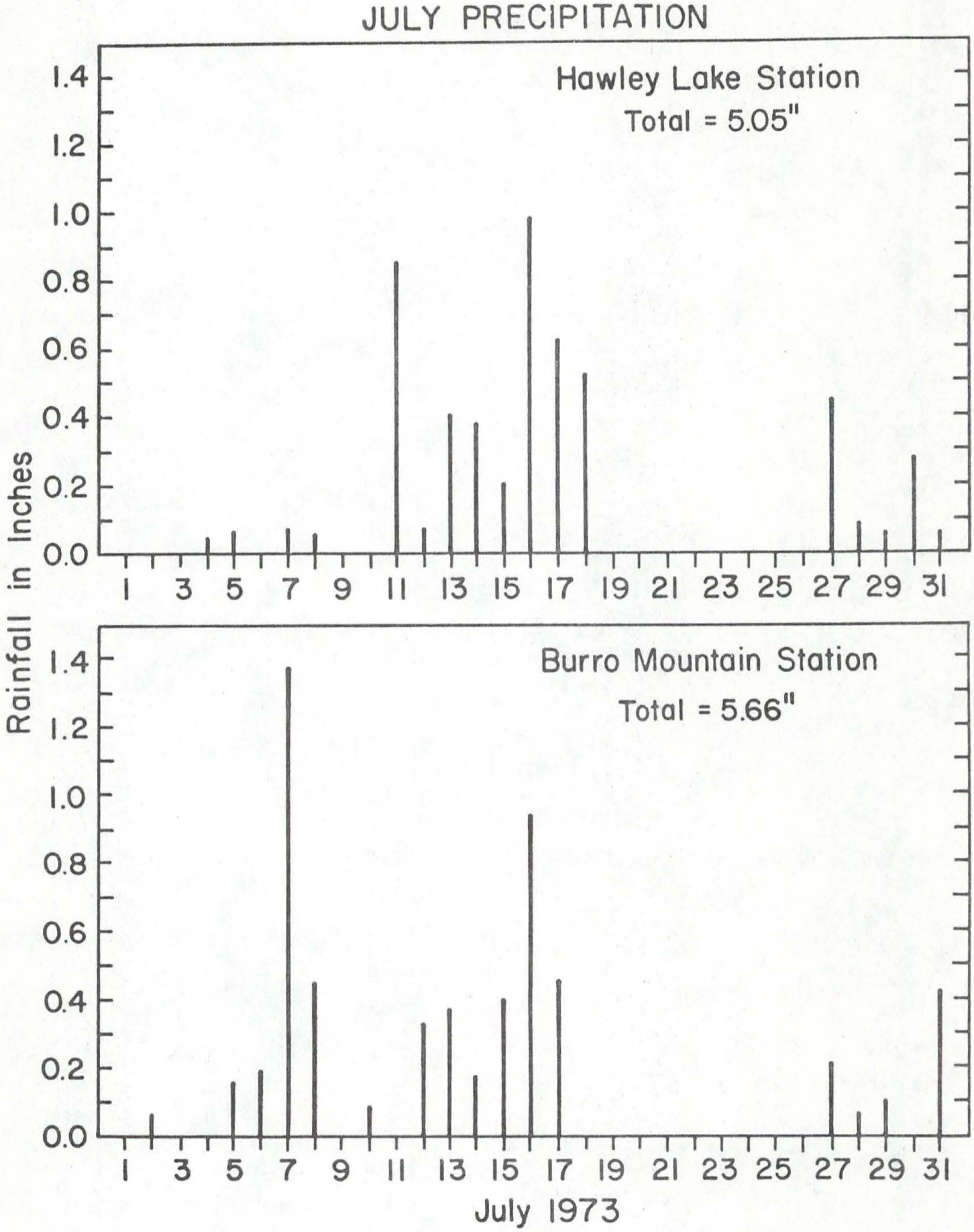

Figure 13. Precipitation events and accumulations for July, 1973: Hawley Lake Station represents Hawley Lake, Trout Creek, Cyclone Lake and North Fork; Burro Mountain Station represents Big Lake and Sheep's Crossing.

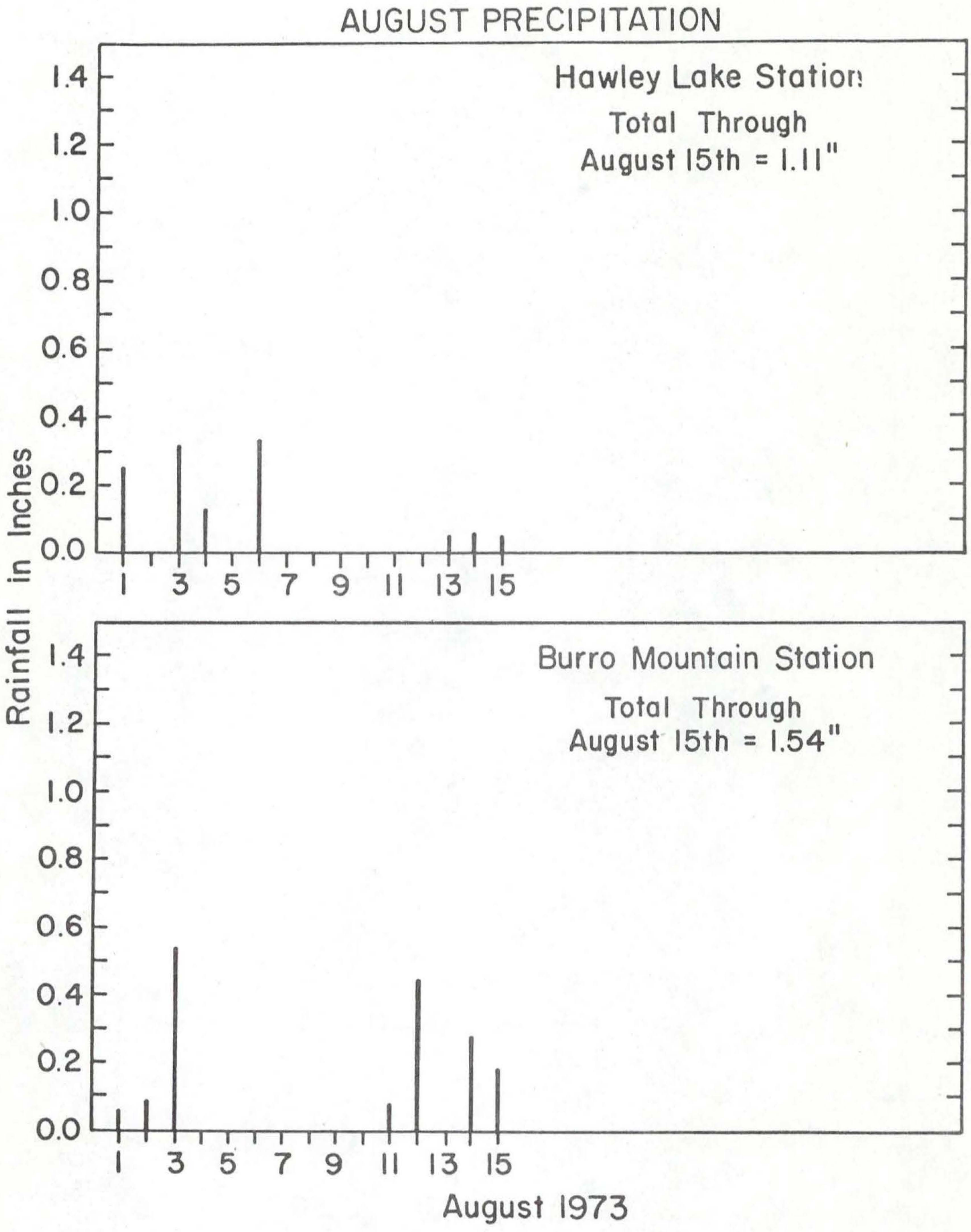

Figure 14. Precipitation events and accumulations for August 1-15, 1973: Hawley Lake Station represents Hawley Lake, Trout Creek, Cyclone Lake and North Fork; Burro Mountain Station represents Big Lake and Sheep's Crossing.

Water Temperature

As water samples were obtained at each study site, water temperatures were also taken and recorded. This variable contributes to the suitability of a water body as an environment. The climate in water is much more even than on land. Variations in temperature take place gradually and the extremes between day and night and the changes in the course of the seasons are relatively small. Nonetheless, small variations in temperature can indirectly describe major conditions within a particular water body.

Temperature data for Big Lake (Figure 15), Cyclone Lake (Figure 16) and Hawley Lake (Figure 17) show all three lakes do stratify. Hawley Lake and Cyclone Lake maintained obvious stratification patterns throughout the summer. Data from the various depths monitored at Big Lake were not as definitely separated. Location, climatological conditions and depth were the most prominent factors influencing the temperature regime of Big Lake. This impoundment is surrounded by open mountain grassland on the east, west and north shores. There are no protective land formations or heavy vegetation (i.e., timber species) adjacent to these shore areas that would act to buffer strong winds occurring in this high country during the summer months. These winds agitate the relatively shallow water of Big Lake and cause more efficient mixing than that developed at the two other research lakes.

Water temperature data for the stream sites (Figure 18) show a definite temperature variation between Trout Creek, North Fork and Sheep's Crossing. Trout Creek was much warmer than the reaches of North Fork or Sheep's Crossing. Extended exposure to solar radiation

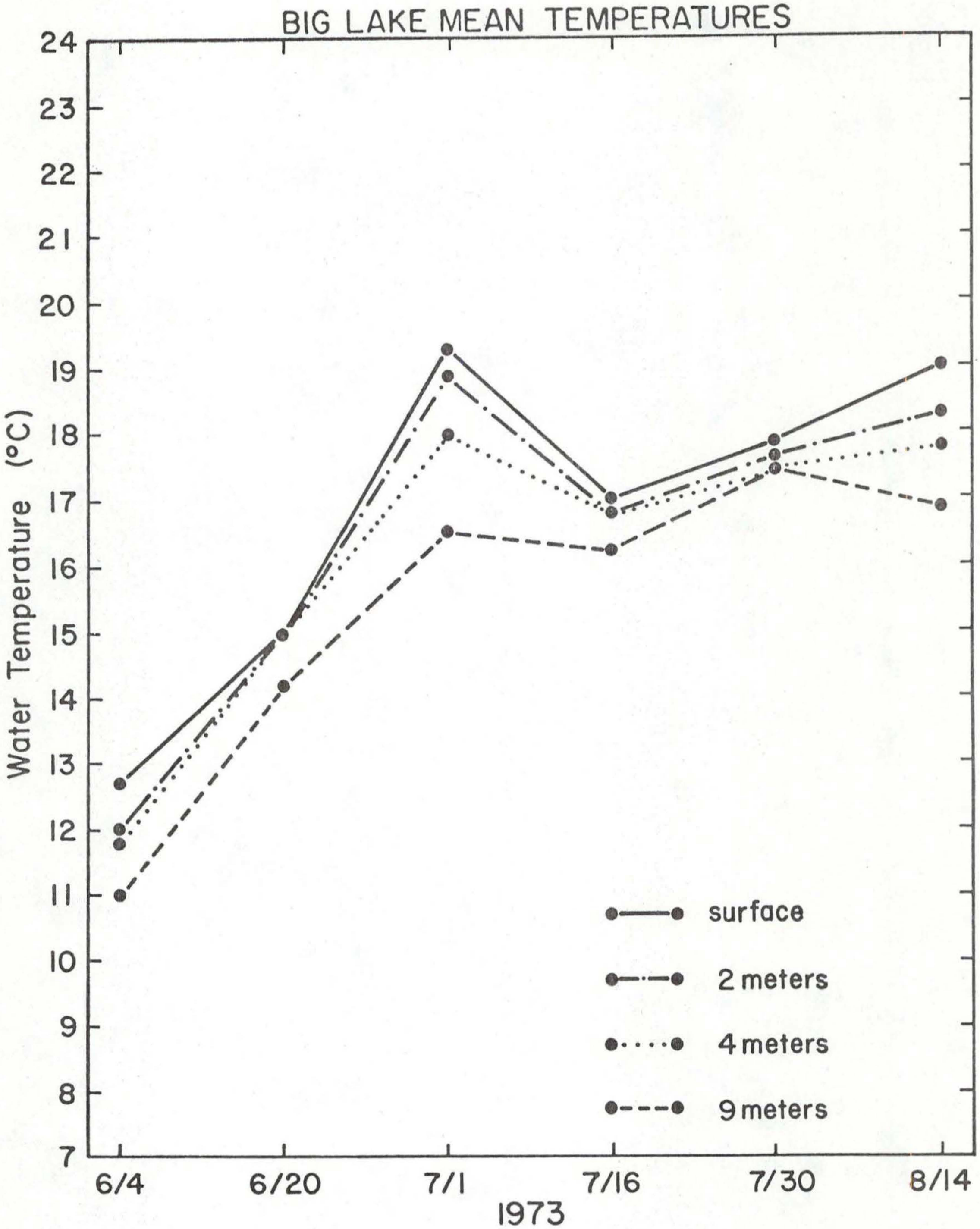

Figure 15. Mean water temperatures per sampling date for surface, 2 meter, 4 meter and 9 meter (bottom) stratifications at Big Lake, 1973.

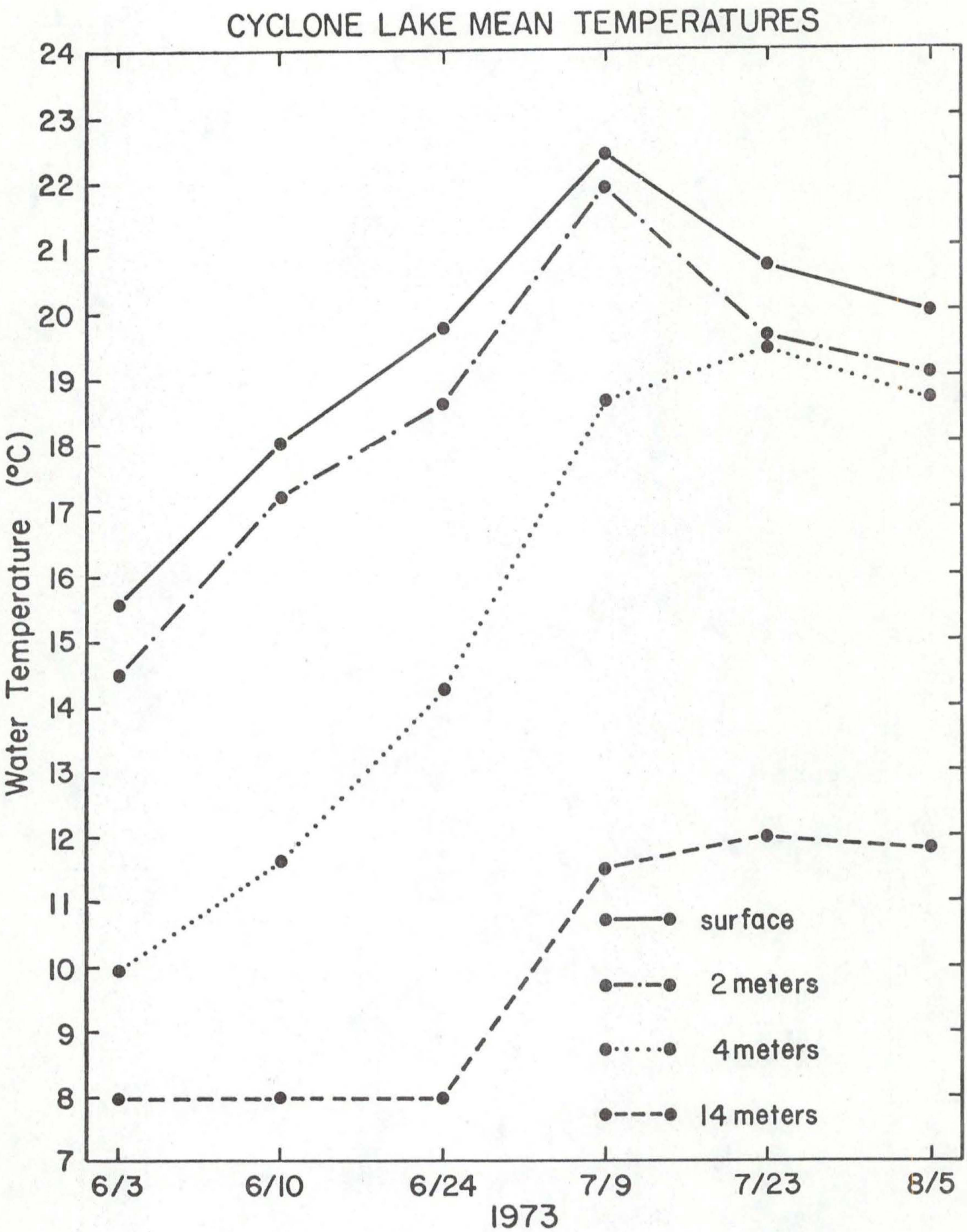

Figure 16. Mean water temperatures per sampling date for surface, 2 meter, 4 meter, and 14 meter (bottom) stratifications at Cyclone Lake, 1973.

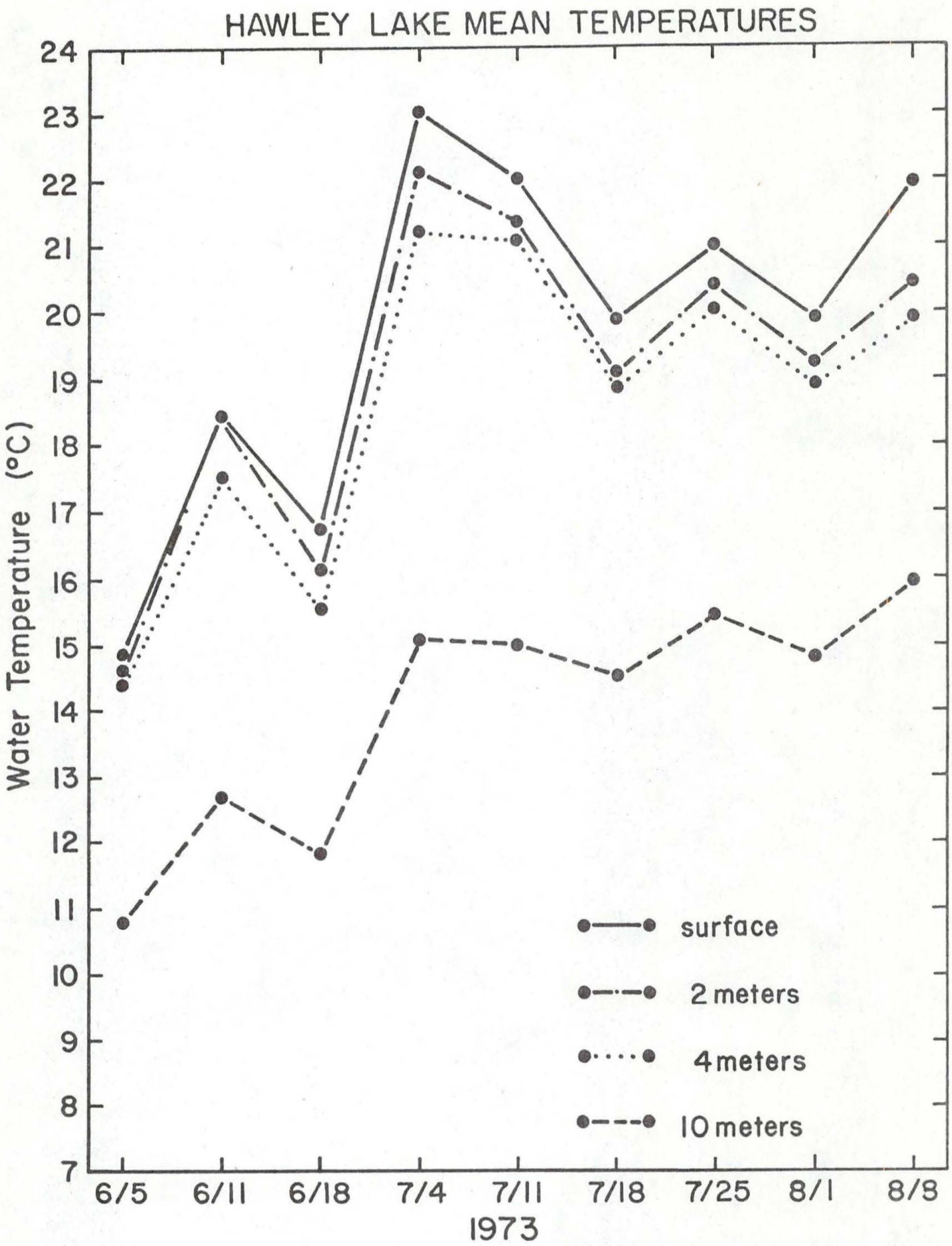

Figure 17. Mean water temperatures per sampling date for surface, 2 meter, 4 meter and 10 meter (bottom) stratifications at Hawley Lake, 1973.

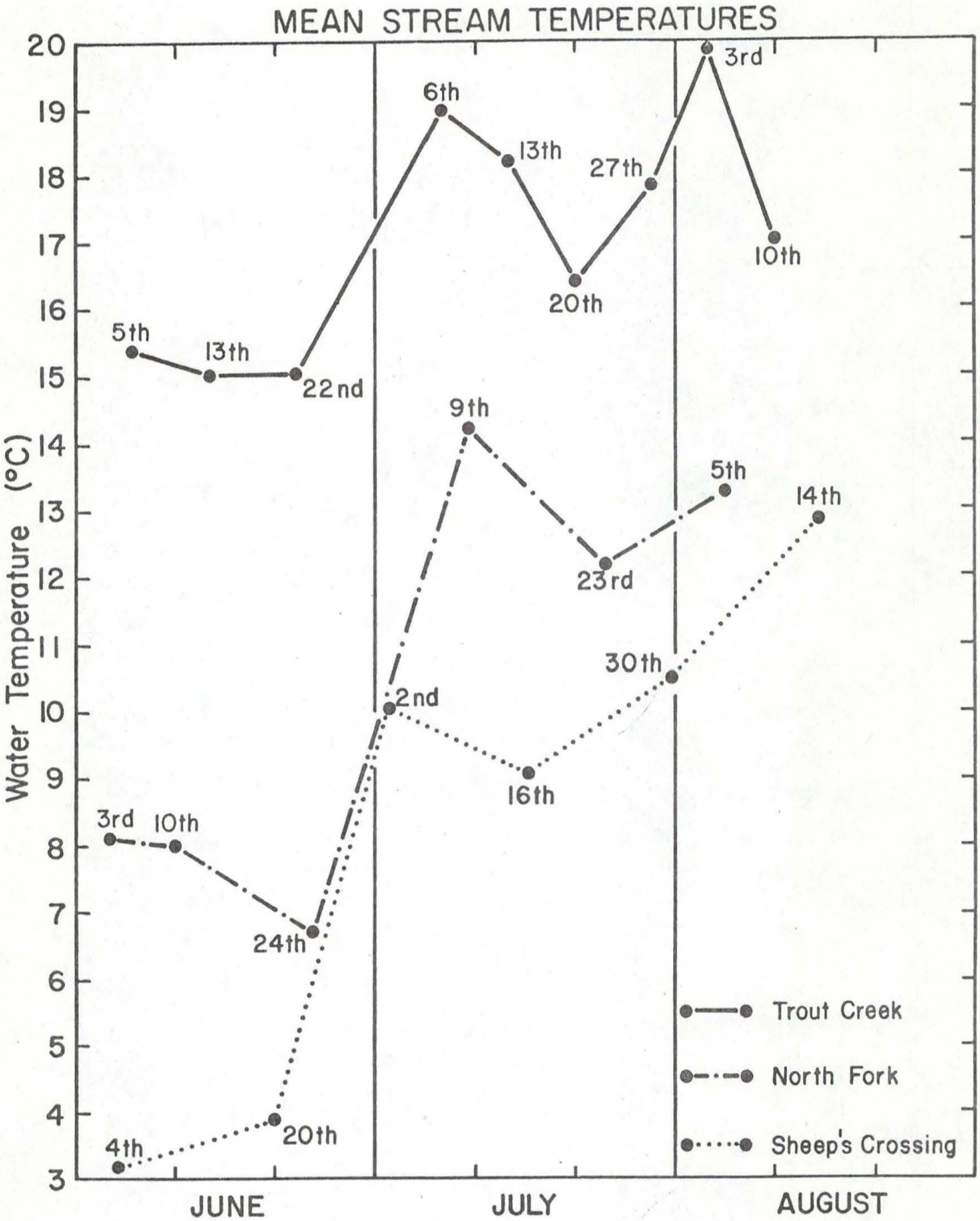

Figure 18. Mean water temperatures per sampling date at Trout Creek, North Fork and Sheep's Crossing, 1973.

was the probable major cause of this difference. Trout Creek, above Hawley Lake, ran only several centimeters deep throughout the sampling season. Flow was also quite slow with no shading vegetation within 100 meters of either bank to protect the stream for 400 meters upstream of the sampling point. North Fork, however, was deeper (0.05 meters), more rapid flowing and moderately protected by vegetative cover, averaging 6°C cooler than Trout Creek during the summer. Sheep's Crossing was cooler than either North Fork or Trout Creek because of a 1,000 foot higher elevation and the location of shade producing spruce and fir trees along the banks.

Turbidity

Secchi disc, or transparency, measurements were employed as turbidity indicators for Big Lake, Cyclone Lake and Hawley Lake. As stated in Section 2 these readings were considered relative turbidity data. A single Secchi disc measurement is not, in itself, of great significance. In relation to a series of measurements conducted over a period of time on the same water body, it represents an integral expression of a major environment factor.

Measurements on the lakes varied only slightly from station to station. Statistical analyses showed no significant differences between stations on any single sampling day. Therefore, mean Secchi disc data were taken from selected stations to represent each research lake.

Big Lake turbidity information (Figure 19) was represented by Stations 1 and 8. The initial measurement on June 4th was relatively shallow, at 2.8 meters. Maximum transparency occurred one month later

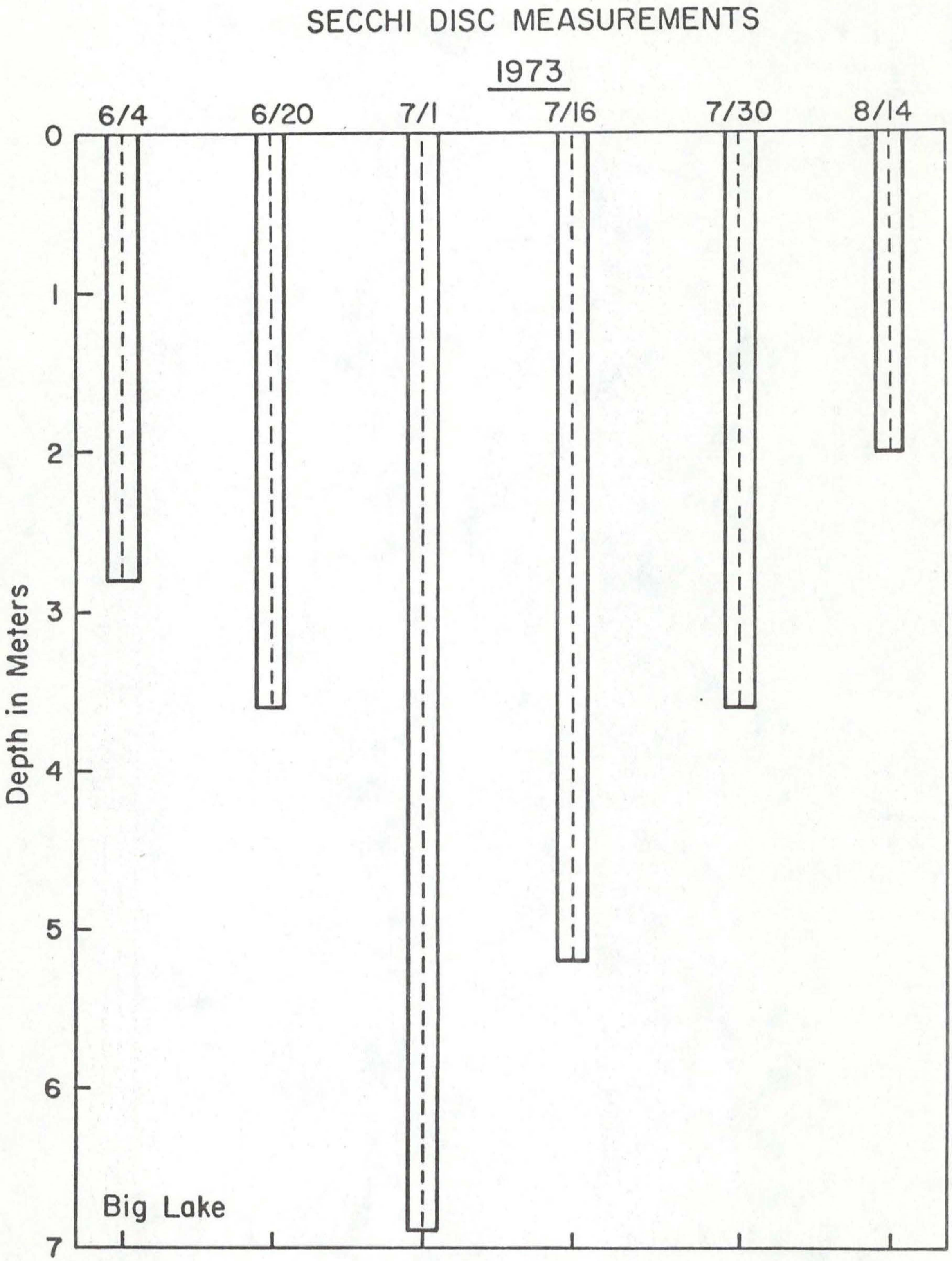

Figure 19. Mean Secchi disc measurements per sampling date at Big Lake, 1973.

on the first of July when the disc could be viewed at a depth of 7.0 meters. Subsequent measurement after this date showed a gradual increase in turbidity. The last sampling day, August 14, resulted in a 2.0 meter Secchi disc measurement.

Transparency data for Cyclone Lake (Figure 20) varied somewhat from that of Big Lake. Secchi disc readings from Stations 3 and 4, for the first half of the sampling season, were relatively low, averaging 2.6 meters. The last three sampling days produced measurements with a mean of 6.0 meters.

A t-test analysis of Hawley Lake Secchi disc readings determined no significant difference between stations on the north and south halves of the lake which were sampled on alternating days. Therefore, Secchi disc data collected at Stations 9 and 11 were used to represent the turbidity factor (Figure 21). Specific measurements were less variable than those of Big Lake and Cyclone Lake. Deepest reading of the sampling period was 5.8 meters recorded June 22nd. The shallowest measurement was registered July 20th, at 3.0 meters. Various other measurements oscillated between these two extremes.

Bacteria

Over the sampling period approximately 800 bacterial culture plates were incubated. Seventy percent of these were fecal coliform cultures; 30 percent were fecal streptococci. Data in Table 3 show the corresponding number of cultures run for each water body.

Of the total sample of fecal coliform cultures approximately 40, exhibiting exotic bacterial colonies not completely restrained by

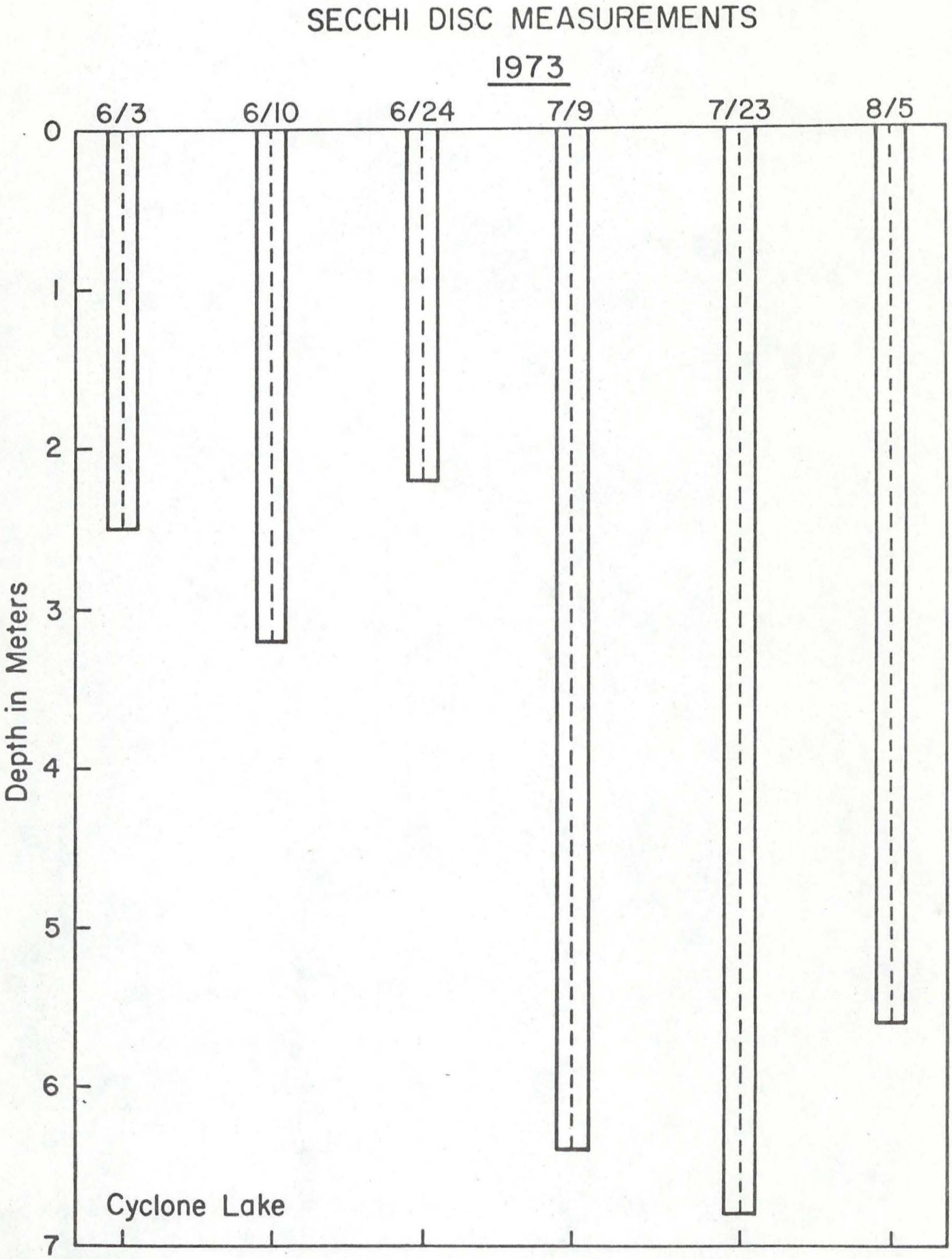

Figure 20. Mean Secchi disc measurements per sampling date at Cyclone Lake, 1973.

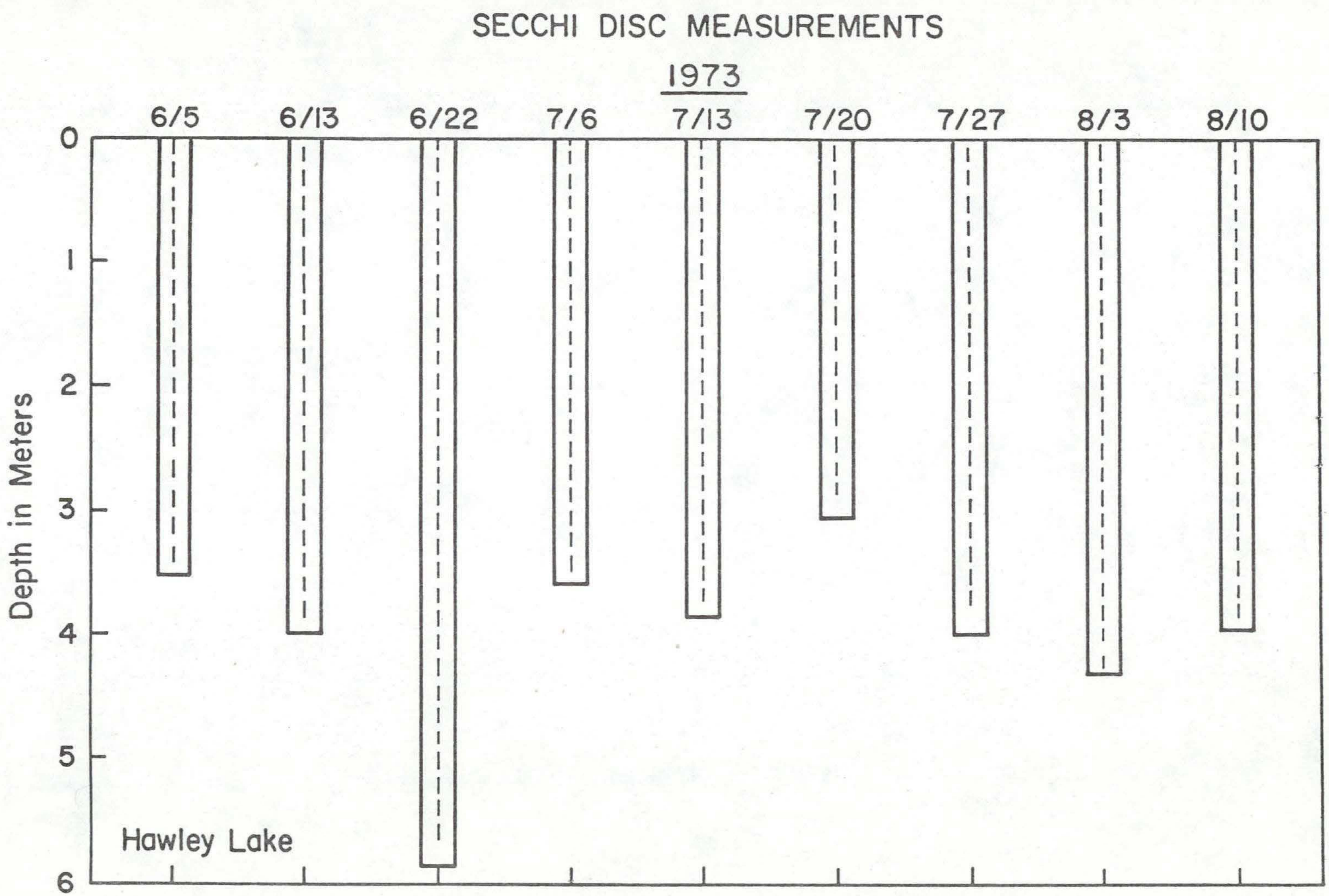

Figure 21. Mean Secchi disc measurements per sampling date at Hawley Lake, 1973.

Table 3. Total number of fecal coliform and fecal streptococci culture plates incubated during 1973 sampling period.

Site Name	Culture Plate Numbers	
	Fecal Coliform	Fecal Streptococci
Hawley Lake	351	91
Big Lake	170	40
Cyclone Lake	91	20
North Fork	18	6
Sheep's Crossing	18	6
Trout Creek	10	5
Total	658	168

inhibiting agents present in the growth media, were analysed and the bacteria identified. A species list of identified bacteria (Table 4) includes Salmonella gallinarum and Proteus vulgaris, isolated from Hawley Lake, which are enterics associated with fowl typhoid and cholera-like epidemics in birds (Breed, Murray and Smith, 1957). Strains of Salmonella and Proteus that infect animals generally do not infect man, although the above two species occasionally produce food poisoning or gastroenteritis in humans. Their presence in Hawley Lake was most readily explained by the presence of 15 to 20 wild mallard ducks (Anas platyrhynchos) on the lake throughout the summer. These waterfowl were often sighted in the vicinities of Stations 1 through 4, 8 and 9.

Two bacterial groups isolated from all of the research waters were species of Pseudomonas and Aerobacter aerogenes which are commonly found in soil and water. The latter are widely distributed and considered not harmful to man (Brock, 1970). Most Pseudomonads act as plant pathogens only and are ecologically important as they are responsible for the degradation of many soluble compounds derived from the breakdown of plant and animal materials. Both these bacterial groups are probably members of the natural lake flora.

Identified from a Hawley Lake culture was Staphylococcus epidermidis, a relatively insignificant parasitic, rather than pathogenic, bacteria. Its habitat is usually the mucus membranes of man and other animals. Also in a sample taken from Station 3 on Hawley Lake and Station 6 at Big Lake was Proteus vulgaris, a bacteria common to putrefying materials (Breed et al., 1957). Both station locations are adjacent to boat dock facilities which often accumulate discarded bait, food

Table 4. Identification of exotic bacteria species produced on m FC agar and waters from which they were isolated.

Organism Name	Location From Which Isolated	
	Water Body	Station
Proteus rettgeri	Hawley Lake	2, 3, 4
Proteus vulgaris	Hawley Lake Big Lake	3 6
Aerobacter aerogenes	All	All
Staphylococcus epidermidis	Hawley Lake	3
Pseudomonas spp.	All	All
Salmonella gallinarum	Hawley Lake	2, 4, 9

and fish carcasses that act as natural habitat for these non-pathogenic bacteria and were their most obvious man caused sources.

Fecal Coliform

Of main concern in this investigation was the monitoring of fecal coliform concentrations in the recreational water bodies under consideration. These bacterial organisms are a normal inhabitant of the intestinal canal of man and other warm-blooded animals. Their presence in a water body is indicative of recent fecal pollution (Geldreich, 1966). As with the exotic bacterial cultures, typical cultures identified by the researcher as fecal coliform organisms were delivered to The University of Arizona for identification. Subsequent presumptive tests, based on gas production from lactose, and elevated temperature tests with EC broth confirmed bacteria identification and laboratory techniques employed in this study.

Fecal coliform concentration data obtained from the separate water bodies are expressed in overall mean numbers of colonies per 100 millilitres of sample. Big Lake (Figure 22) and Cyclone Lake (Figure 23) exhibited very low numbers of fecal indicator organisms. Big Lake showed a maximum, overall mean fecal coliform concentration of 10 colonies per 100 millilitres the second week of July. Cyclone Lake peaked at a mean of 4.5 colonies the final sampling day of August 5th. Hawley Lake (Figure 24) also displayed minimal indicator concentrations from the first sampling day until the second week of July at which time there was a large increase to a maximum, mean concentration of 150 organisms per 100 millilitres. This peak number then decreased to the

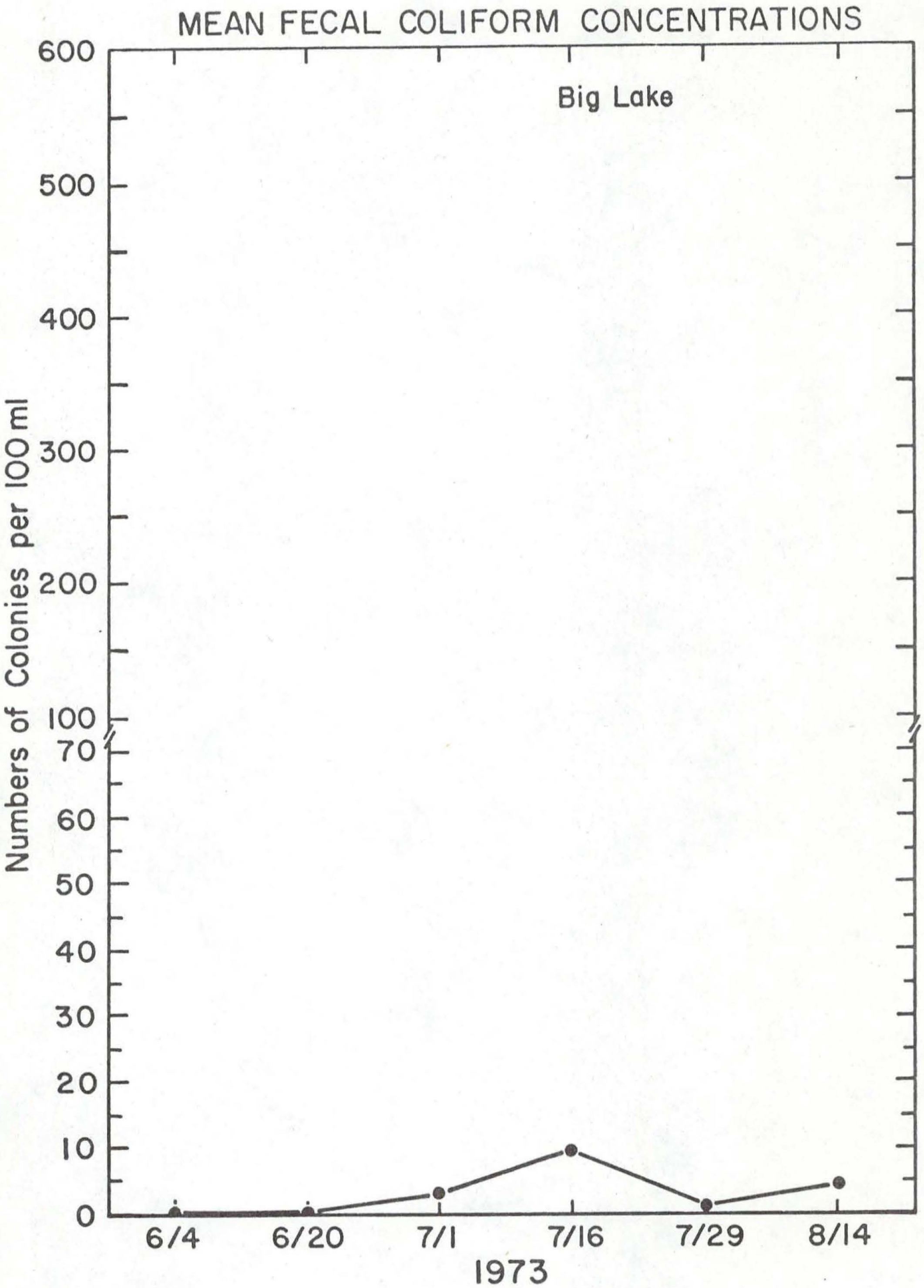

Figure 22. Mean fecal coliform concentrations per sampling date at Big Lake, 1973.

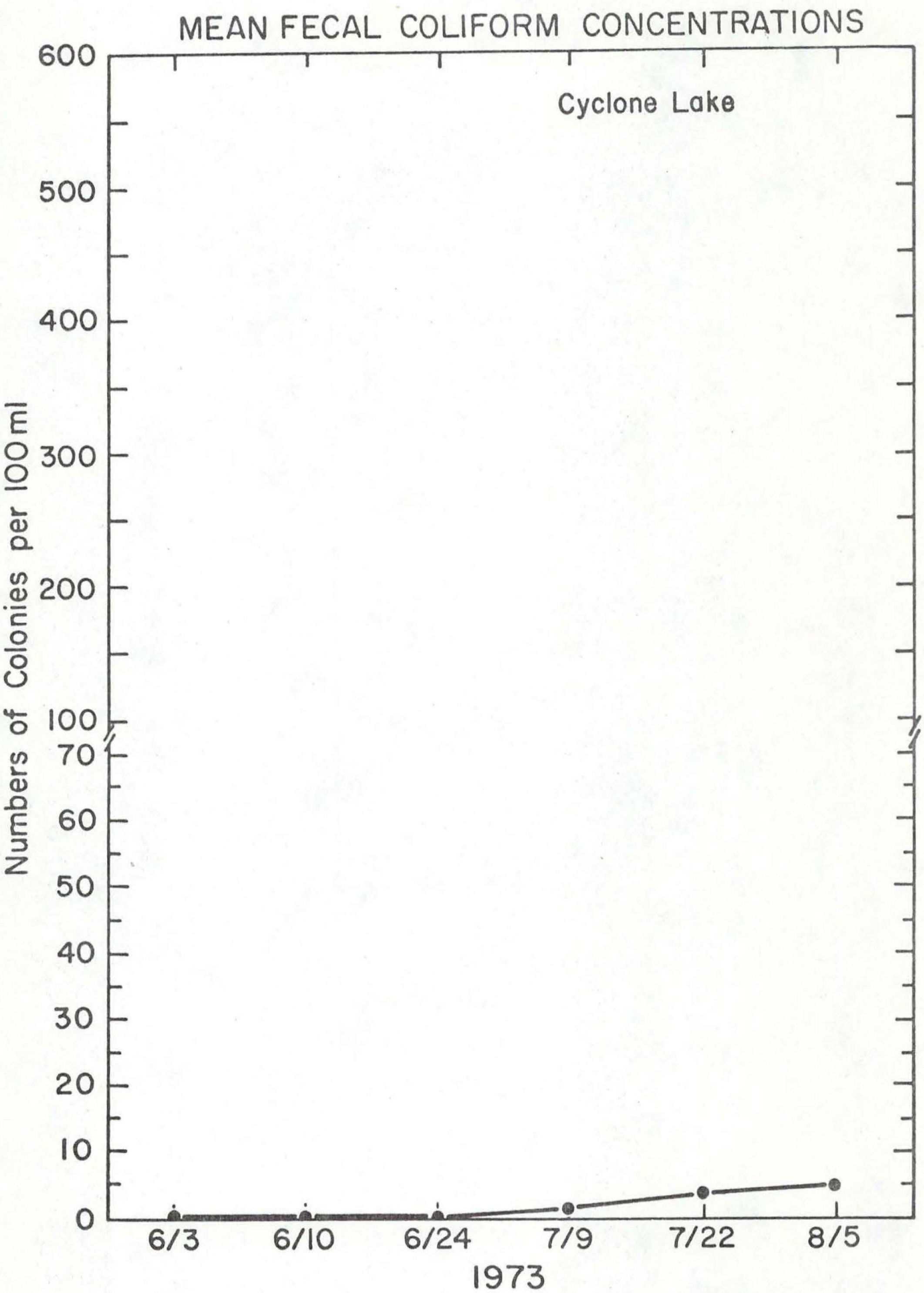

Figure 23. Mean fecal coliform concentrations per sampling date at Cyclone Lake, 1973.

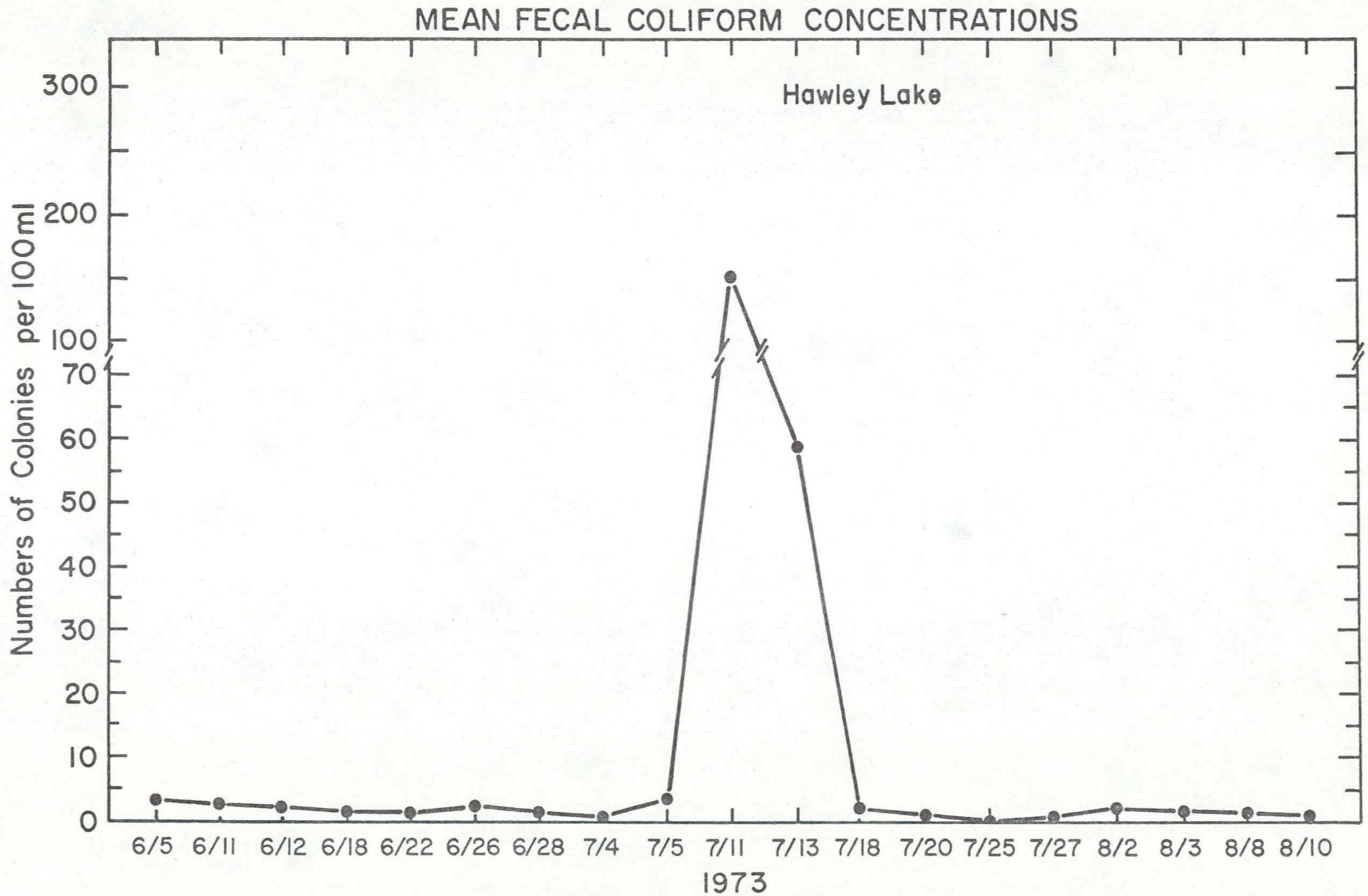

Figure 24. Mean fecal coliform concentrations per sampling date at Hawley Lake, 1973.

original low bacterial concentration recorded in June and continued at that level during the remainder of the investigation.

Most dramatic of the indicator organism concentrations recorded for the 3 streams were those of Trout Creek (Figure 25). Numbers were low to moderately high through June but beginning the first week of July, which recorded 600 colonies per 100 millilitres, bacterial numbers increased and persisted at concentrations above 125 colonies per 100 millilitres through August 10th. Data show that after the early July peak, bacteria numbers dropped and then rose again at the end of the study period to over 400 colonies per 100 millilitres. Initially, it would appear as though Trout Creek, registering 600 colonies per 100 millilitres on July 5, had the greatest concentration of bacteria recorded in the course of the study. However, the numbers for this stream were not mean numbers but represented direct counts from the single sampling station on Trout Creek. Table 5 indicates the highest organism count recorded for any one sampling station to be Station 2 at Hawley Lake.

Both North Fork (Figure 26) and Sheep's Crossing (Figure 27), from June through the second week of July, displayed similar fecal coliform patterns. Mean numbers were relatively low (less than 10 colonies per 100 millilitres) during June and increased to a maximum of 68 colonies per 100 millilitres at each stream in early July. Bacterial numbers then decreased sharply at North Fork to concentrations similar to those in June and again increased while Sheep's Crossing exhibited a gradual decrease maintaining mean indicator organism concentrations above 45 colonies per 100 millilitres the last two sampling days.

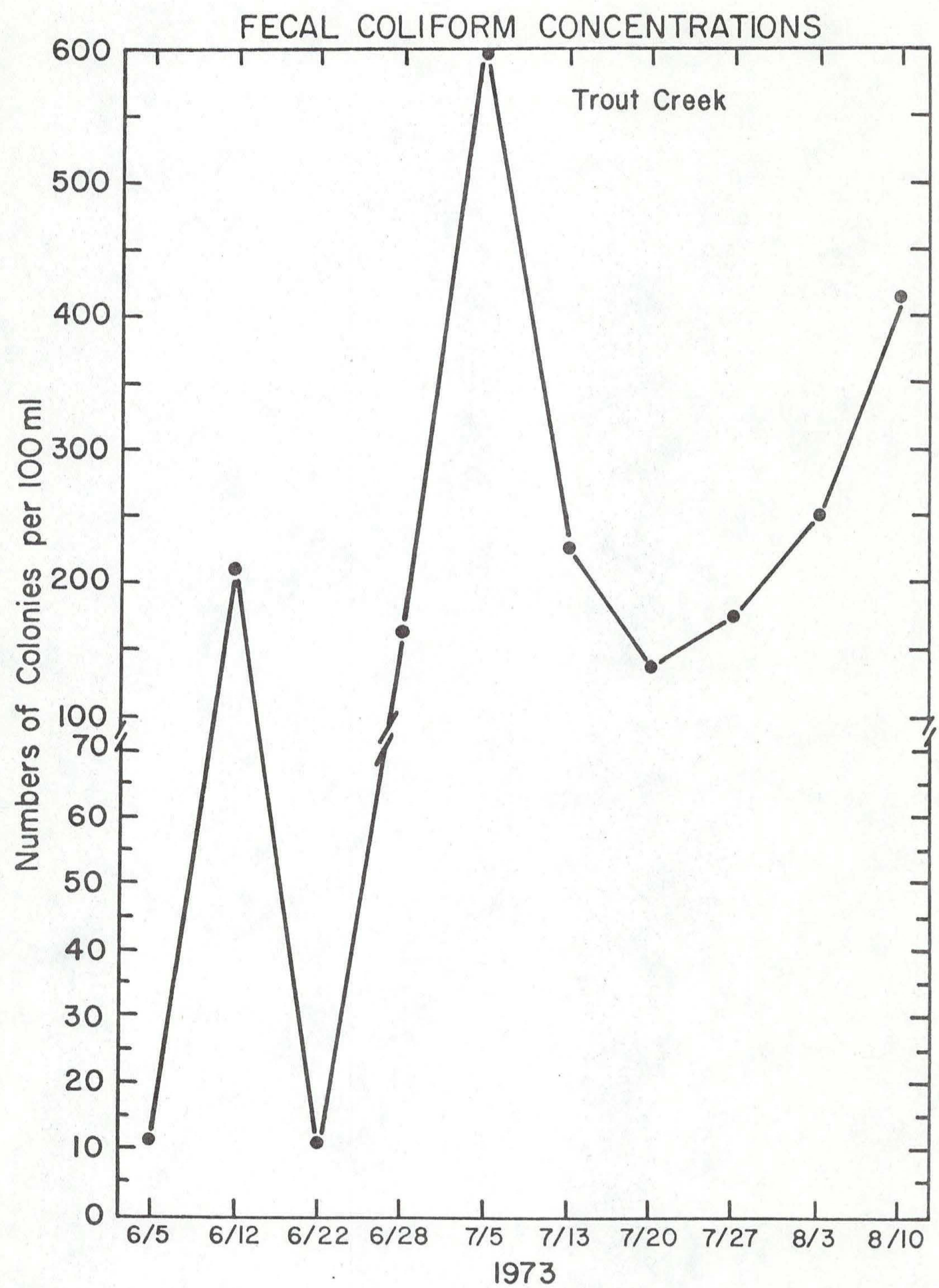

Figure 25. Mean fecal coliform concentrations per sampling date at Trout Creek, 1973.

Table 5. Maximum fecal coliform colony concentrations recorded for any one sampling station at each water body.

Water Body Name	Maximum Recorded Fecal Coliform Concentrations			
	Date	Station	Depth	Number/100 ml.
Big Lake	17 July	7	5.7 m	142
Cyclone Lake	5 August	2	2.0	26
Hawley Lake	11 July	2	surface	800
Trout Creek	5 July	1	surface	590
North Fork	9 July	3	surface	101
Sheep's Crossing	16 July	1	surface	105

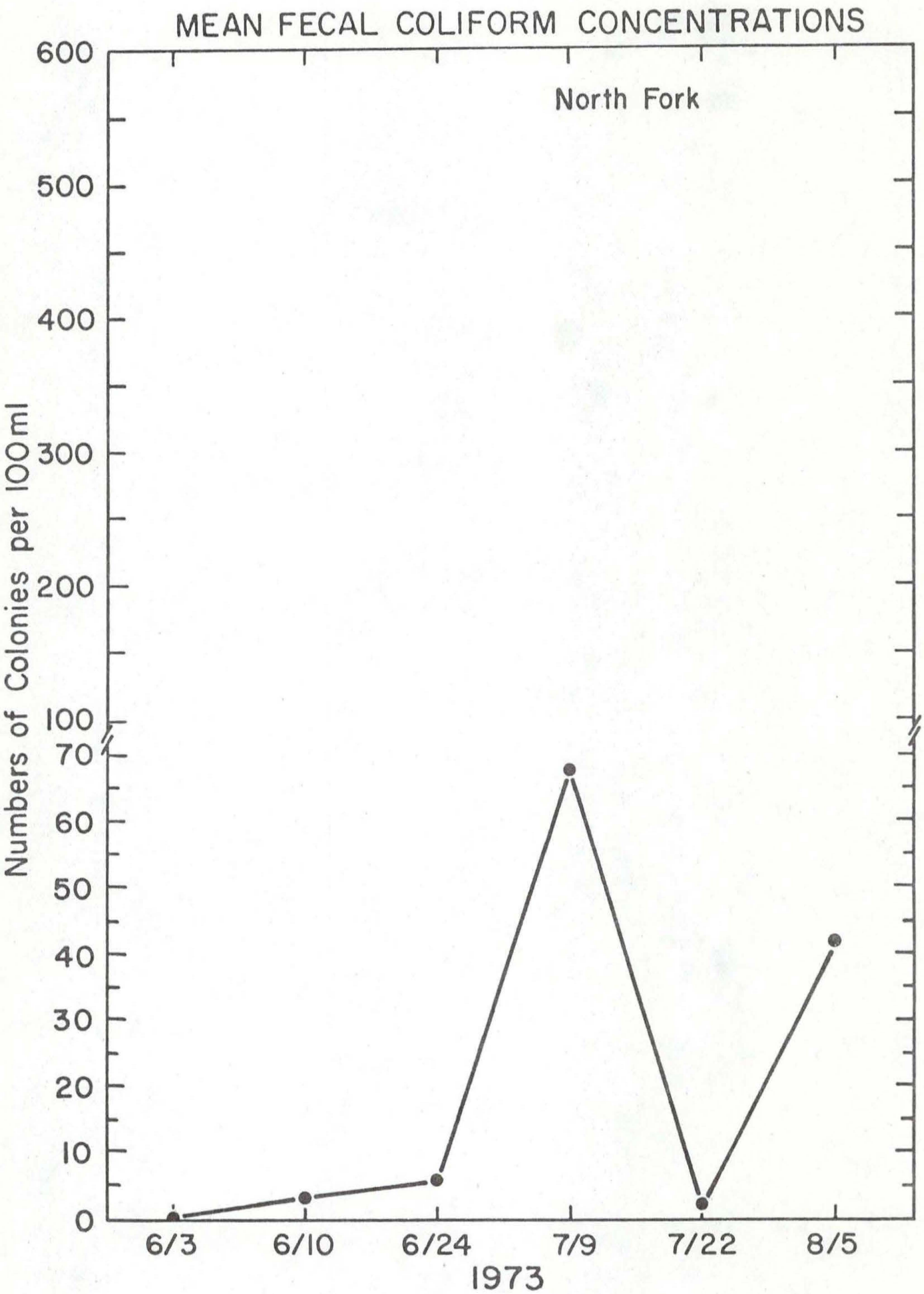

Figure 26. Mean fecal coliform concentrations per sampling date at North Fork, 1973.

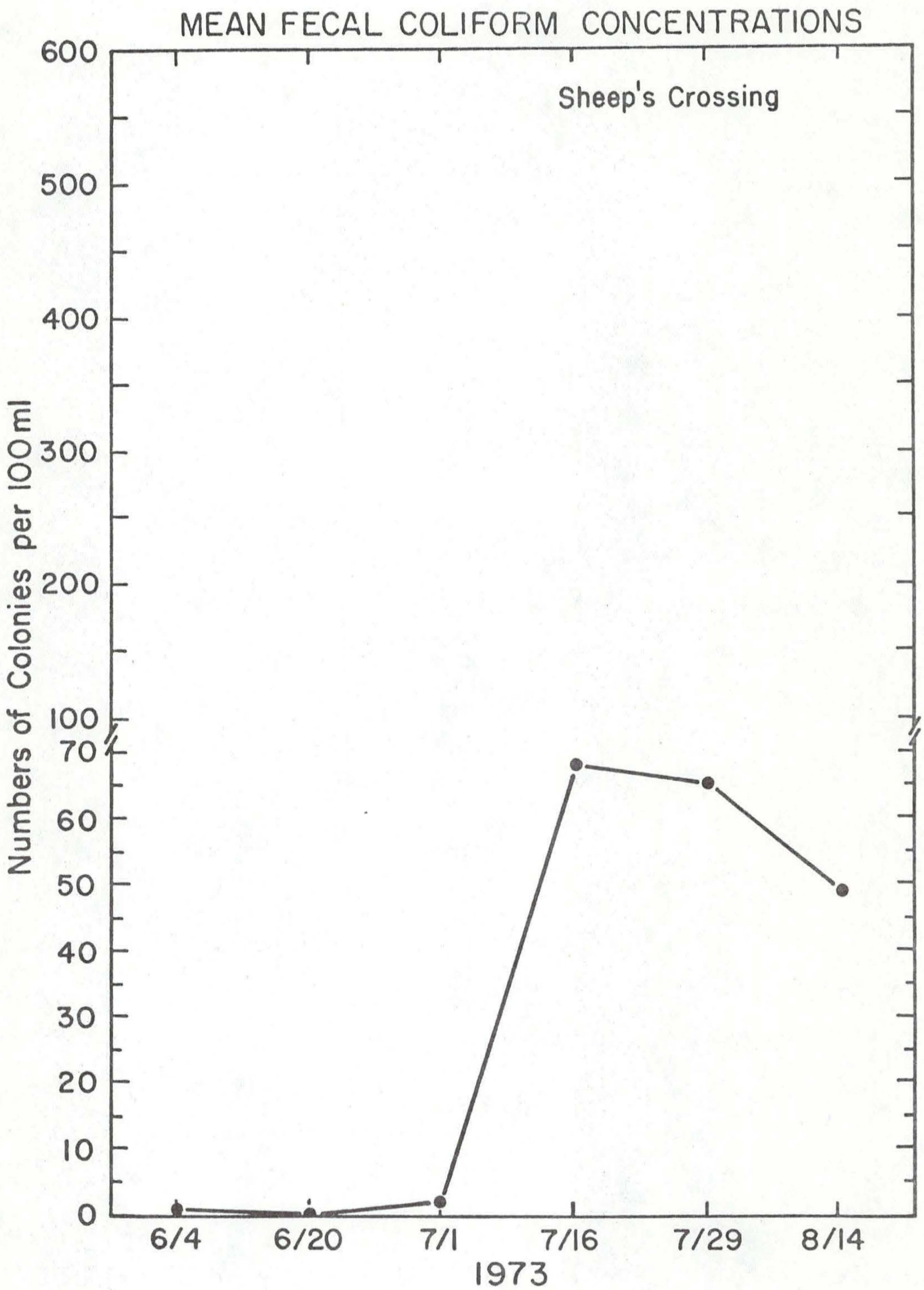

Figure 27. Mean fecal coliform concentrations per sampling date at Sheep's Crossing, 1973.

Fecal Streptococci

Fecal streptococci bacteria inhabit the intestine of man and other warm blooded animals. They are more tolerant of environmental extremes and more resistant to anti-bacterial agents than are coliform bacteria. Also, fecal streptococci survive longer in water than do coliforms; hence they are not used as indicators of recent pollution but their concentrations are generally combined with other bacterial information (i.e., fecal coliform numbers) to aid in contaminant source identification.

Fecal streptococci data were collected at various times in the summer to project their values into ratio determinations with fecal coliform bacteria. Such ratios from any investigation must be interpreted carefully since bacterial densities in polluting wastes can be affected by adverse conditions including high or low pH, intense dryness and ultraviolet light. These and other antagonistic environmental characteristics can drastically reduce or alter bacterial populations. Keeping this in mind, certain ratio values may be applied to specific sources of warm blooded animal pollution based on natural ratios of fecal coliform and fecal streptococci organisms in the fecal matter of various warm blooded animals (Table 6).

Ratios greater than 4:1 usually indicate the pollution is derived from domestic wastes which are largely composed of man's body wastes, laundry wastes and food refuse. Ratios of less than 0.7 suggest the pollution is derived from dog, cat, wildlife, or livestock wastes. Values between these two ratios are common to mixed pollution. Resultant ratio determinations from this investigation are given in Table 7.

Table 6. Per capita contribution of fecal coliform and fecal streptococci bacteria from several animals.[a]

	Average Density Per Gram Feces		Average Contribution Per Capita Per 24 Hours		
Animal	F. Coli million	F. Strep. million	F. Coli. million	F. Strep. million	FC/FS
Man	13.0	3.0	2,000	450	4.4
Duck	33.0	54.0	11,000	18,000	0.6
Cow	0.23	1.3	5,400	31,000	0.2

[a]Coliform data from Geldreich, Bordner et al. (1962). Fecal streptococci data from Kenner, Clark and Kabler (1961).

Table 7. Fecal coliform to fecal streptococci ratio results showing only those data with large enough bacterial counts from both groups to permit ratio development.

Location	Date	Station	Depth meters	F. Coli./ 100 ml.	F. Strep./ 100 ml.	FC/FS
Hawley Lake	6/26	1	4.0	1.3	40.6	0.03
	6/26	6	surface	2.0	31.2	0.06
	7/4	2	surface	273.0	17.3	15.8
	7/4	3	7.1	1.0	31.4	0.03
	7/4	5	4.1	1.0	400.0	0.003
	7/4	7	2.0	10.0	3,600.0	0.003
	7/5	11	7.0	4.0	148.0	0.03
	7/5	13	3.1	34.3	40.0	0.85
Big Lake	6/20	7	5.7	8.0	14.6	0.54
Cyclone Lake	6/24	6	surface	1.0	29.5	0.03
	8/5	1	2.0	12.6	64.0	0.24
North Fork	8/5	1	surface	14.4	32.8	0.44
	8/5	3	surface	11.2	30.4	0.37
Trout Creek	6/26	1	surface	43.2	13.6	3.17
Sheep's Crossing	6/20	1	surface	4.0	80.0	0.05

Visitor Use

As an index of visitor use vehicle counts were made for each study site on individual sampling days. All vehicles present at the Sheep's Crossing, Cyclone Lake and North Fork research sites are represented in the data. Prohibitive numbers and locations of vehicles at Big Lake and Hawley Lake required the establishment of a less comprehensive counting procedure. Vehicle numbers from the campgrounds were selected to serve as indicators of visitor use for these two lakes.

Big Lake is a popular recreation area which receives a majority of its use during the summer months as do the other project sites. Visitor use for this lake (Figure 28) at the beginning of the water sampling season was approximately 50 percent capacity of established facilities. Use later increased to a maximum the first week of July then decreased through the middle and end of that month. A second visitaiton peak, slightly less than that observed is July, was recorded at the end of the summer sampling period in mid-August.

Cyclone Lake, the least intensively used impoundment studied, received a great deal less use than Big Lake, never exceeding the maximum of 15 vehicles recorded the first sampling day of the investigation (Figure 29). Vehicle numbers made a general decline through the summer to a low of 5 vehicles observed the final sampling day.

Visitation for the Hawley Lake and Trout Creek area is represented by Figure 30. This area displayed the most intensive and greatest variety of use. Vehicle numbers from the campground made a gradual increase from early to late June. A substantial rise in visitation produced maximum vehicle counts the first week in July. These high numbers

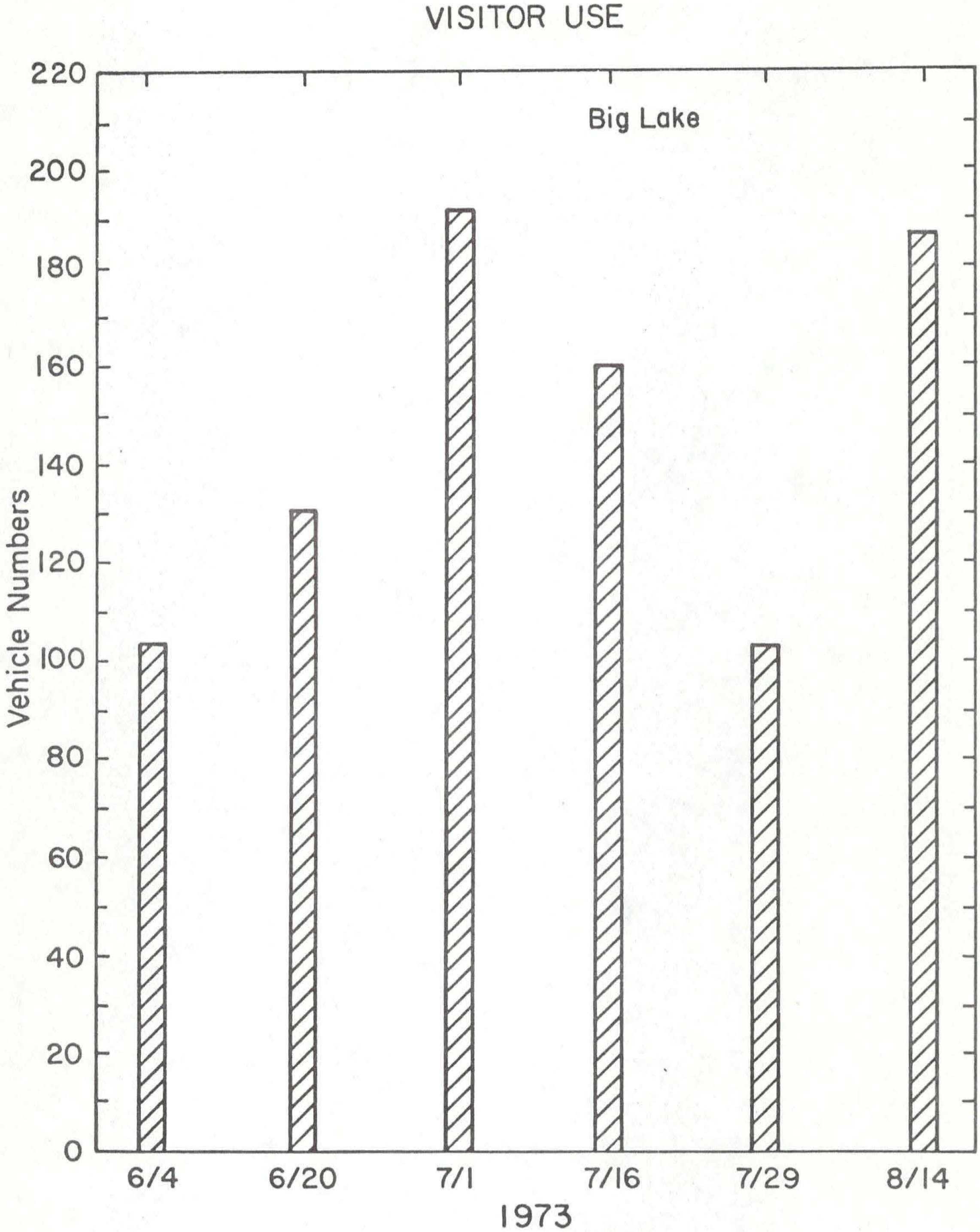

Figure 28. Number of vehicles present per sampling date at Big Lake campgrounds, 1973.

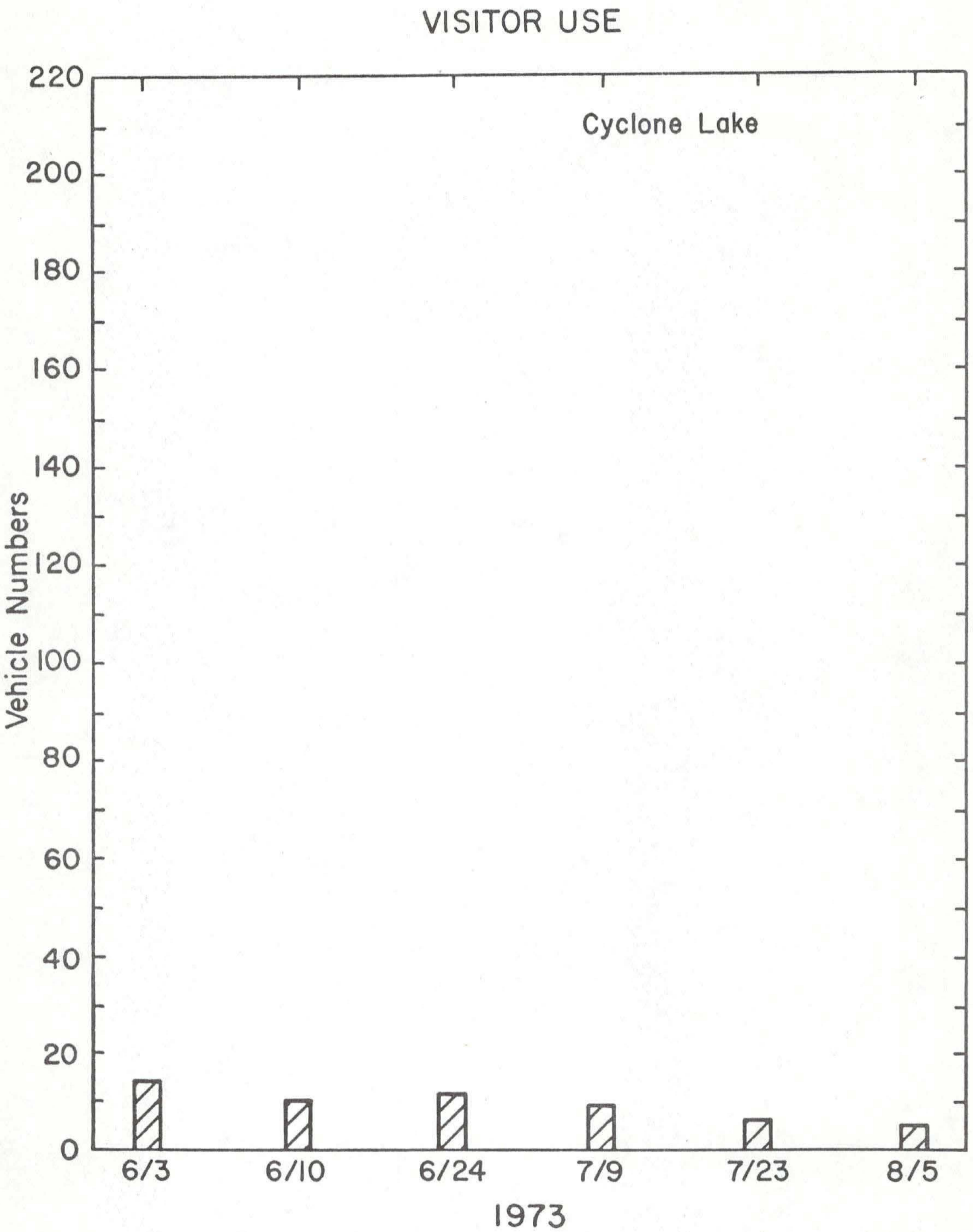

Figure 29. Total number of vehicles present per sampling date at Cyclone Lake recreation area, 1973.

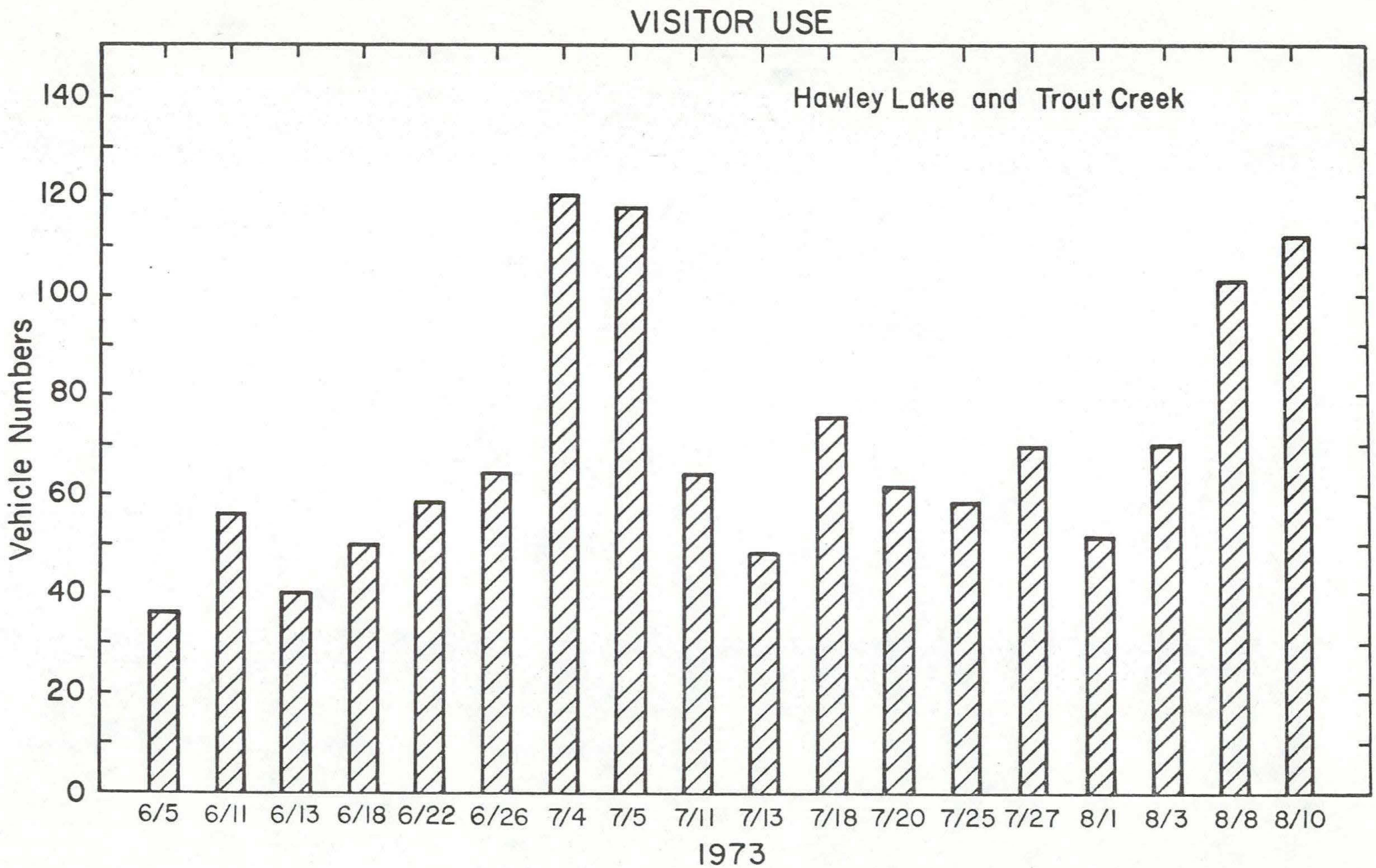

Figure 30. Number of vehicles present per sampling date at Hawley Lake campground, 1973.

were quickly followed by relatively moderate visitation through the end of July. High visitor numbers, slightly lower than the initial July peak were observed in August. The peak use periods at both Big Lake and Hawley Lake occurred in similar patterns.

North Fork (Figure 31) and Sheep's Crossing (Figure 32) both demonstrate, on a much smaller scale, visitor use patterns much like those observed at Hawley Lake and Big Lake. Relatively low numbers in June increased to maximum counts in early July, decreased at the end of that month and peaked again in August.

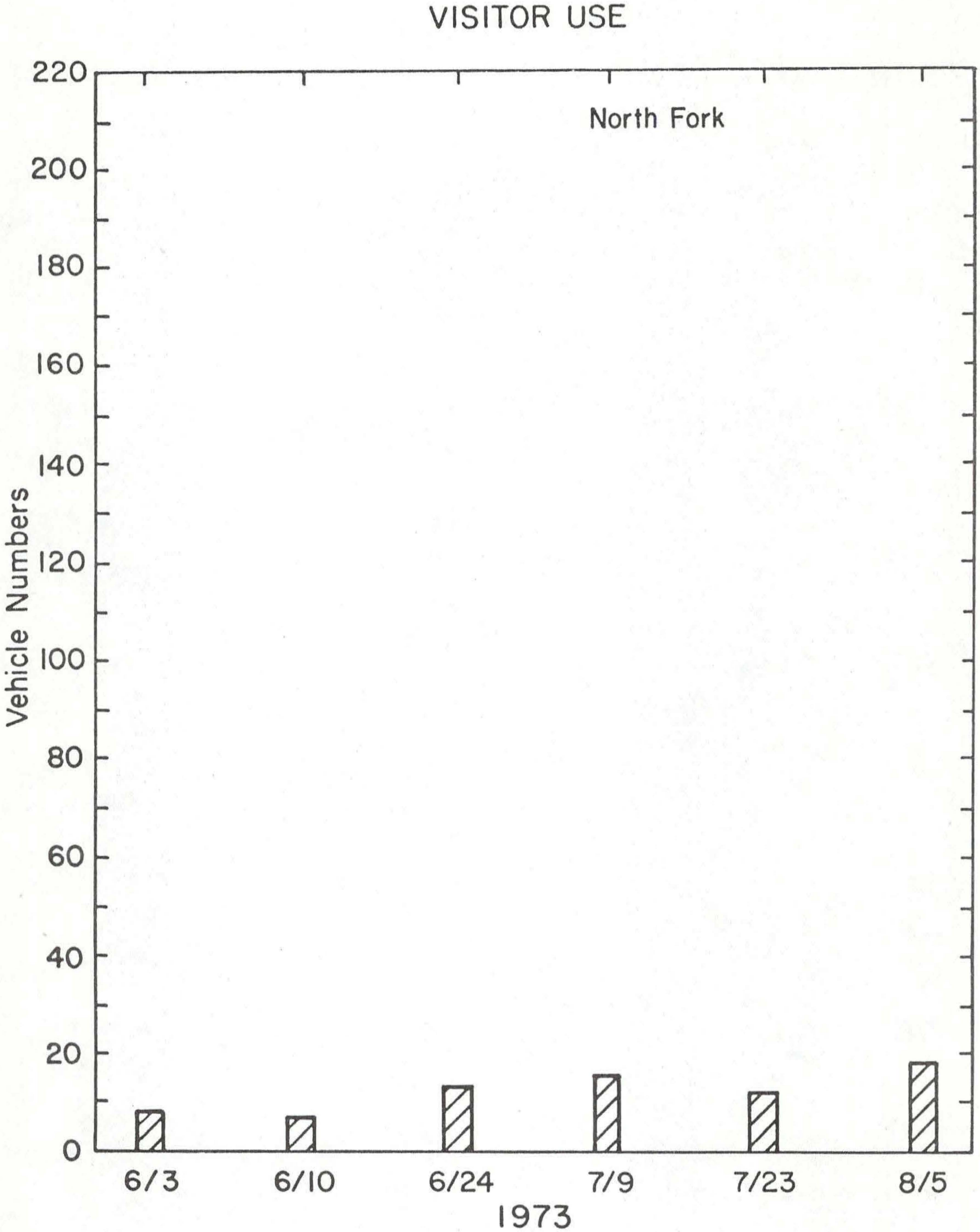

Figure 31. Total number of vehicles present per sampling date at North Fork recreation area, 1973.

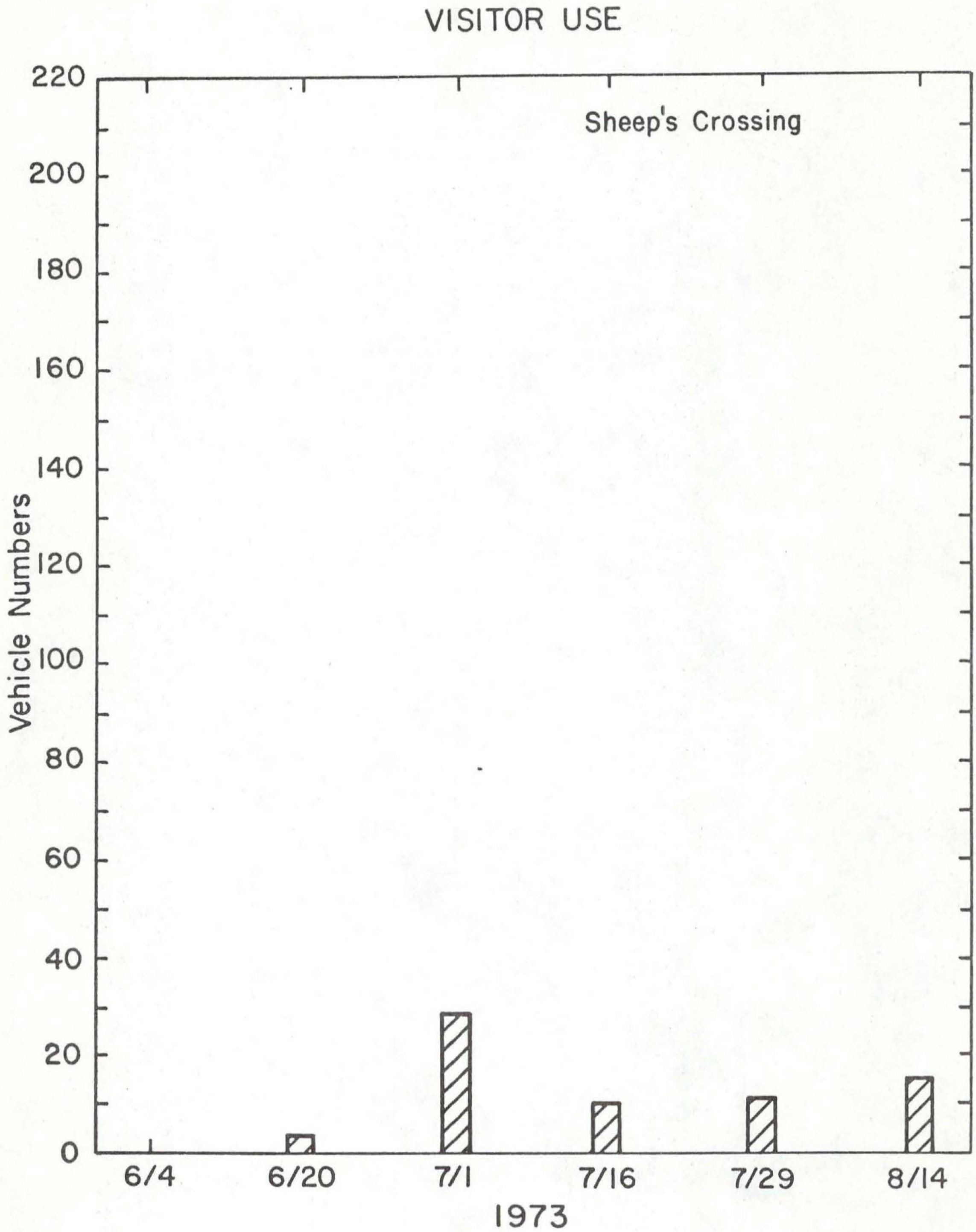

Figure 32. Total number of vehicles present per sampling date at Sheep's Crossing recreation area, 1973.

SECTION 4

RESULTS AND DISCUSSION

In Chapter 5 general data results and those showing significant differences or associations, that are indicative of or serve to explain possible water quality problems, are described. Related computations are exhibited in accompanying tables.

Hawley Lake data are discussed first and in a manner that describes general characteristics common to all three study lakes. Big Lake and Cyclone Lake analyses follow and are presented together for comparative purposes.

Stream information concerning North Fork and Sheep's Crossing results are discussed concurrently. Trout Creek data are presented separately; this stream site was appended to the project in 1973 and has no 1972 comparative data.

Statistical Tests

Results of Student's t-tests and bivariate correlation analyses are presented for each research site. t-tests were calculated to determine differences between populations within individual water bodies and between populations in separate water bodies. Also included were tests between data populations obtained in 1973 and those reported for the same waters by Brickler and Lehman (1973) from 1972 summer field research. Correlation coefficients were computed to determine significant associations between 1973 research variables. An alpha level of 0.05

was employed for both t-tests and correlation coefficients. Significance levels for "t" and "r" were obtained from Snedecor and Cochran (1967).

Hawley Lake

Physical Factors of Hawley Lake. Temperature data from Hawley Lake show stable stratification by the first sampling date in June. This meant that for a few weeks in spring, prior to stratification, water temperatures were homogeneous from the surface of the lake to the bottom. Vertical water density was also homogeneous and it was possible for wind to mix the lake water, distributing nutrients and flocculent bottom solids from deeper areas. The advance of summer quickly checked circulation by warming the surface water; as it warmed it became lighter, resting over the colder water of greater density. Thus, a thermally stratified water environment was formed.

Stratified lakes form three layers. The upper layer, or epilimnion, consists of warmer, more or less, freely circulating water. A middle layer, or thermocline, is the region of rapid temperature change and limited mixing. The lower layer, or hypolimnion is the cold region of approximately uniform temperature. It is cut off from circulation with upper waters.

Mean June temperatures at Hawley Lake were significantly cooler than those of July or August (Table 8), although there was no difference detected between the July and August sampling periods. This pattern is descriptive of the gradual response of water bodies to changes in climatological conditions. In June, warm summer air temperatures were

Table 8. Student's t-test results indicating a significant difference between June and July water temperatures at Hawley Lake.

	Hawley Lake Student's t-test Results						
Variable	Groups	No. of cases	Mean °C	Standard Deviation	t value	Degrees of Freedom	Significance Level
Water temperature	June	44	17.1	2.4	2.32[a]	47	2.00
	July	48	20.8	1.7			

[a]Separate variance estimate of t.

prevalent but the lake water, still cool from spring temperatures, was only slowly absorbing this heat. Gradually the lake warmed to a mean maximum of 20°C the first week of July and maintained warm temperatures through the study period.

Hawley Lake recorded 4 scattered days of precipitation the first half of June. Almost no rainfall was recorded between June 15 and July 10. On July 11 nearly one inch of precipitation fell with continued rain for 7 consecutive days accumulating 4.01 inches. This intense wet period had a significant effect on bacteria numbers, which is more fully described in the section on bacteriological factors. Additional precipitation was experienced the end of July and 1.11 inches fell during the first 15 days of August. These latter rainfall events were of lesser intensity than those of mid-July.

Mean Secchi disc measurements at Hawley Lake for the field periods of June, July and August were statistically homogeneous. The absence of a significant increase between mean Secchi disc measurements reocrded in June (period of least precipitation) and mean measurements recorded in July (period of greatest precipitation) indicated the immediate watershed of Hawley Lake had sufficient ground cover protection in summer, 1973 to prevent erosion from significantly increasing turbidity at the time of heaviest precipitation. There was, however, a significant correlation between precipitation and the small changes in Secchi disc information for the heavy rain period of early July (Table 9). This signifies the potential for an erosion-turbidity problem exists should extensive denudation and trampling occur from overuse at Hawley Lake.

Table 9. Bivariate correlation results exhibiting a significant correlation of July precipitation with Secchi disc, or relative turbidity, measurements at Hawley Lake.

	Hawley Lake Bivariate Correlation Results			
Variables	Groups	Degrees of Freedom	Significance Level	Correlation (r)
Precipitation	July	22	.404	-.411
Secchi disc measurements	July			

Chemical Factors of Hawley Lake. pH at Hawley Lake averaged 7.5 during the sampling period. As was stated in Chapter 4 this slightly basic condition is common to natural waters and is determined by surrounding soil characteristics and decomposition and respiration processes. The range of 7.0 to 8.0 included all study sites over the field period and was not sufficient to have effected significant changes in other monitored variables. In addition, pH measurements were well within the range of 5.0 to 9.0, favorable to survival of fish (Doudroff and Katz, 1950) which are a major recreation element for the White Mountains in general.

Nutrient levels observed for Hawley Lake in 1973 were representative of moderately eutrophic conditions. The overall mean concentration of nitrate nitrogen was 3.01 ppm and that for ortho-phosphate was 0.061 ppm. As no significant difference was found between nutrient levels of the 3 lakes investigated it was determined nutrient conditions were largely influenced by natural watershed characteristics common to the area. Although ortho-phosphate concentrations remained relatively uniform at Hawley Lake over the summer, nitrate nitrogen levels from surface waters in June were significantly greater than in July and those of July were found to be higher than August concentrations (Table 10). This pattern was not unusual for a lake of this type. During summer stagnation (after spring turnover) there is a clearly recognizable nutrient stratification in many moderately eutrophic lakes (Ruttner, 1963). The main cause of this phenomenon is gradual utilization of nutrients by phytoplankton in the epilimnion. Ortho-phosphate reduction

Table 10. Student's t-test results indicating a significant difference between June and July surface nitrate nitrogen concentrations and also between July and August concentrations at Hawley Lake.

	Hawley Lake Student's t-test Results						
Variable	Groups	No. of cases	Mean ppm	Standard Deviation	t value	Degrees of Freedom	Significance Level
Surface nitrate nitrogen	June	24	3.37	0.77	2.64[a]	69	2.00
	July	47	3.05	1.41			
	July	47	3.05	1.41	2.15[a]	49	2.01
	August	12	2.50	0.52			

[a]Separate variance estimate of t.

over the sampling period probably lacked statistical detection not because it did not occur but because it was less strongly expressed.

Tests between 1972 and 1973 Hawley Lake nutrient data determined nitrate nitrogen and ortho-phosphate concentrations were higher in 1973 (Table 11). Although no obvious natural or man related causes could be identified the fact that all three lakes displayed increased nutrient levels in 1973, in addition to no significant difference being identified between nutrient levels of the separate lakes that year, indicated the influence of a common factor.[3]

Climatological conditions in the White Mountains at the time of spring turnover could have generated more effectual mixing in 1973 than that in 1972. This, along with organism movement and eddy diffusion, would have brought more benthic material into upper waters which would have allowed greater concentrations of nutrients to be brought into solution.

Bacteriological Factors of Hawley Lake. Comparisons of 1973 Hawley Lake data with those of both Big Lake and Cyclone Lake showed that Hawley Lake displayed one significant dissimilarity. Mean fecal coliform concentrations for the summer sampling period were greater at Hawley Lake (Table 12). This would imply Hawley Lake received more fecal pollution than the other two impoundments.

In Section 3 graphical presentation of fecal coliform concentrations at Hawley Lake (Figure 24) shows mean numbers of organisms as

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3. The lack of significant differences between 1972 and 1973 nutrient concentrations for Sheep's Crossing or North Fork acted to rule out laboratory technique or equipment error.

Table 11. Student's t-test results indicating significant differences between 1972 and 1973 nutrient concentrations at Hawley Lake.

	Hawley Lake Student's t-test Results						
Variables	Groups	No. of cases	Mean ppm	Standard Deviation	t value	Degrees of Freedom	Significance Level
Nitrate nitrogen	1972	50	2.2	0.89	4.77[a]	132	1.98
	1973	84	3.0	0.98			
Ortho-phosphate	1972	41	0.032	0.016	6.63[b]	107	1.99
	1973	69	0.061	0.030			

[a]Pooled variance estimate of t.

[b]Separate variance estimate of t.

Table 12. Student's t-test results indicating significant differences between Hawley Lake fecal coliform concentrations and those of Big Lake and Cyclone Lake.

	Hawley Lake Student's t-test Results						
Variable	Groups	No. of cases	Mean No./100 ml.	Standard Deviation	t value	Degrees of Freedom	Significance Level
Fecal coliform bacteria	Hawley	121	24.4	105.9	2.20[a]	122	1.98
	Big	48	3.2	6.2			
	Hawley	121	24.4	105.9	2.32[a]	121	1.98
	Cyclone	36	2.0	2.0			

[a]Separate variance estimate of t.

quite low (less than 5 colonies per 100 millilitres) on the majority of sampling dates. The exception was a two week period in early July during which the overall mean concentrations rose to 150 colonies per 100 millilitres.

Analysis of fecal coliform data for the first two weeks of July, comparing intensively and lightly developed areas of Hawley Lake, indicated significantly higher bacteria numbers occurred in surface waters of the more intensively developed lake area (Table 13). No differences were evident between sub-surface stratifications. Sampling Stations 1-5, and 9 represented the more intensively developed portion of Hawley Lake (see Figure 2) and were, for the most part, located on the southern portion of the lake. Little or no development was present in the areas near Stations 6, 7, 8, 11, 12 and 13; this appeared to be reflected in the relatively limited bacterial contamination detected at these locations.

Analyses of Hawley Lake (1973) data showed a strong correlation of surface fecal coliform numbers with overall mean fecal coliform concentrations (Table 14). Insignificant correlations were obtained when bacteria numbers from 2 meter, 4 meter and bottom depths were compared with overall mean numbers. Surface bacterial concentrations significantly effected overall mean numbers by skewing the distribution.

Recent studies have indicated fecal coliform bacteria may be relatively concentrated in bottom sediments as was suggested by Van Donsel and Geldreich (1971 and 1972). Fecal coliform organisms which survive extended exposure to predators (i.e., protozoans) and hostile water environments tend to sink and accumulate in bottom sediments in

Table 13. Student's t-test results indicating a significant difference between surface fecal coliform concentrations of intensively developed and lightly developed areas the first two weeks of July, 1973 at Hawley Lake.

	Hawley Lake Student's t-test Results						
Variable	Groups	No. of cases	Mean No./100 ml.	Standard Deviation	t value	Degrees of Freedom	Significance Level
Surface fecal coliforms	Intensive	12	205.4	280.8	2.19^{a}	12	2.18
	Light	12	15.6	52.1			

[a]Separate variance estimate of t.

Table 14. Bivariate correlation results exhibiting a significant correlation of surface fecal coliform numbers with overall fecal coliform concentrations at Hawley Lake.

	Hawley Lake Bivariate Correlation Results			
Variable	Groups	Degrees of Freedom	Significance Level	Correlation (r)
Fecal coliform bacteria	surface overall mean numbers	119	.181	.913

greater concentrations than in overlying waters. Deep water and the absence of bathers and other bottom disturbing agents at Hawley Lake would explain the low numbers of fecal bacterial organisms isolated from waters overlying bottom sediments.

To determine factors associated with the higher fecal coliform numbers recorded at Hawley Lake in the month of July a correlation between precipitation and bacteria was calculated. Results showed a positive correlation of precipitation with bacteria numbers (Table 15). This correlation was most important for it indicated a definite route of bacterial contamination for Hawley Lake. Higher fecal coliform bacteria numbers were apparently closely related to the "flushing effect" (Kunkle and Meiman, 1967) of early summer storms on the watershed.

Because precipitation contains insignificant bacterial contamination, its major contamination source is contact with a polluted land environment. Soil in areas away from man receives low levels of occasional contamination from wildlife and generally contains few fecal coliform organisms (Geldreich, Huff et al., 1962). In contrast, soil in areas frequented by man receives varying levels of warm-blooded animal pollution from humans, pets, livestock and rodents. As a result, soil contributes fluctuating densities of fecal contamination to runoff water, the amount being related to intensity and frequency of soil pollution.

Survival of fecal coliform bacteria in soil and their transfer to stormwater is related to many factors (Van Donsel et al., 1967). Some of the factors include sunlight exposure of the soil, temperature, frequency of rainfall, soil moisture, soil pH, organic matter, frequency

Table 15. Bivariate correlation results exhibiting a significant correlation of July fecal coliform concentrations with precipitation at Hawley Lake.

	Hawley Lake Bivariate Correlation Results			
Variables	Groups	Degrees of Freedom	Significance Level	Correlation (r)
Surface Fecal Coliforms	July	46	.288	.381
Precipitation	July			

of recontamination and the presence of competing or antagonistic organisms.

Because of the intensive recreational use and development of Hawley Lake, water sampling schedules were purposely designed to permit more frequent sampling at Hawley Lake than Big Lake or Cyclone Lake. However, concerns were raised associated with the more frequent sampling at Hawley Lake: (1) the sampling schedule for Hawley Lake substantially increased the probability of one or more sampling days coinciding with the detected bacterial flushing effect, and (2) the large fecal bacteria counts recorded as a result of the flushing effect of the second week of July at Hawley Lake may have over represented bacterial data at this impoundment in relation to that of Big Lake and Cyclone Lake. As a test for over representation, additional statistical comparisons of 1973 data were made for the three study lakes excluding Hawley Lake data recorded the second week of July. Results showed no significant differences between fecal coliform data of Hawley Lake and Big Lake, or Cyclone Lake. Therefore, Big Lake and Cyclone Lake may have had bacterial flushing effects, comparable to that at Hawley Lake, which were not detected because of less frequent sampling schedules. This would make somewhat questionable, the previously mentioned implication that Hawley Lake received greater fecal contamination than did Big Lake or Cyclone Lake.

The numerous low and erratic fecal coliform and fecal streptococci bacterial concentrations at Hawley Lake (and all other study sites) made it difficult to apply resultant ratios as determinants toward definite identification of specific contaminant sources (i.e., human-nonhuman). The majority of relatively low concentrations of

bacteria isolated and used in the ratios of Table 7 (Section 3) in relations to the millions present in the fecal material of humans and other animals (Table 6) indicated that a great decrease in concentration had taken place from the initial period of animal elimination to the time of actual sampling. Ratios determined from the data are uncertain. Fecal coliform to fecal streptococci ratios are dependable only if examined water samples are collected no more than 24 hours from the time of bacterial source introduction (Kittrell, 1969). Twenty-four hour contaminant sources could not be identified at the study sites.

Visitor Use of Hawley Lake. No significant correlations were identified for Hawley Lake visitation with any monitored variables. The pattern of gradually increasing visitor use during the month of June to the Fourth of July (day of heaviest summer visitation) was considered to have been indirectly associated with the significant correlation of precipitation with July surface fecal coliform concentrations. Increasing numbers of humans and pets at the lake during the dry weeks of June and early July were probably responsible for the majority of fecal material on the watershed. This material would have caused increased concentrations of fecal coliform organisms in water samples taken during the "flushing effect" period of the first summer storms.

Big Lake and Cyclone Lake

Physical Factors of Big Lake and Cyclone Lake. Although Big Lake was 1,000 feet higher (and thus, cooler) than Cyclone Lake, temperature patterns of both impoundments conformed to the general summer

trend described for Hawley Lake. Cool mean temperatures in June increased to maximums in early July and continued warm through the sampling period. Cyclone Lake remained well stratified, as did Hawley Lake. Big Lake also was stratified but temperature separations between stratifications were not as distinct, becoming nearly homogeneous the latter part of July. This less pronounced stratification at Big Lake was further evidenced by a significant, positive correlation of precipitation with bottom temperature (Table 16). Bottom temperatures of a well stratified lake are not significantly affected by surface disturbances. However, summer storms, accompanied by strong winds, were capable of overcoming the less firmly established thermal stratification at Big Lake and causing exchange between the hypolimnion and overlying warmer waters.

Precipitation patterns for Big Lake and Cyclone Lake were quite similar. Sampling season totals amounted to 8.50 and 8.13 inches, respectively. No significant correlations were determined for rainfall with any physical or chemical factors at either lake other than that described above for bottom temperatures at Big Lake.

Mean Secchi disc measurements recorded for Big Lake and Cyclone Lake in 1973 were not found to be significantly different from those of 1972. Also, no differences were determined between overall mean Secchi disc data from each of the three study lakes in 1973. Visual observation of Secchi disc data (Figures 19 through 21) does show an obvious difference in patterns of variation. As discussed previously, Secchi disc readings at Hawley Lake maintained relatively uniform measurements, while Big Lake readings increased the first half of the season and

Table 16. Bivariate correlation results exhibiting a significant correlation of precipitation with bottom temperature at Big Lake.

		Big Lake Bivariate Correlation Results		
Variables	Groups	Degrees of Freedom	Significance Level	Correlation (r)
Precipitation	Summer	37	.317	.329
Temperature	Bottom			

decreased the latter half. Cyclone Lake exhibited a trend opposite that of Big Lake.

No significant correlations were identified for Secchi disc data with other physical variables for Cyclone Lake and Big Lake. Comparison of the previously mentioned Secchi disc illustrations with those exhibiting water temperature data (Figures 15 and 16) indicates the temperature regimes of these two lakes (in regard to their effect on stabilization) were primary factors influencing turbidity. In addition, the absence of significant physical factor correlations with Secchi disc data, and the existence of obvious variability within the summer season, would suggest plankton organisms were a main turbidity component (Stull, 1974). This appeared to be the case at Big Lake where a progressive plankton bloom was observed the latter portion of the sampling period, reducing Secchi disc measurements to one-third the mean maximum season reading.

Chemical Factors of Big Lake and Cyclone Lake. Nutrient concentrations in 1973 were greater at Big Lake and Cyclone Lake than those recorded for the same areas in 1972 (Table 17). A more effective spring turnover in 1973 was the most probable cause of this difference. There was no difference between the three project lakes in 1973.

Nutrient concentrations within Big Lake did not change significantly over the summer sampling period. Effective mixing at Big Lake could have maintained nutrient levels even during utilization by increased plankton populations. A significant decrease in surface nitrate nitrogen between Cyclone Lake July and August samples was identified

Table 17. Student's t-test results indicating significant differences between 1972 and 1973 nutrient concentrations for both Big Lake and Cyclone Lake.

	Big Lake and Cyclone Lake Student's t-test Results						
Variables	Groups	No. of cases	Mean ppm	Standard Deviation	t value	Degrees of Freedom	Significance Level
Big Lake nitrate nitrogen	1972	50	2.16	1.01	3.68[a]	88	1.99
	1973	40	2.90	0.85			
Big Lake ortho-phosphate	1972	46	0.032	0.014	4.39[b]	30	2.04
	1973	28	0.074	0.050			
Cyclone Lake nitrate nitrogen	1972	54	2.18	1.01	3.82[a]	82	2.00
	1973	30	3.00	0.76			
Cyclone Lake ortho-phosphate	1972	53	0.039	0.028	2.64[b]	27	2.05
	1973	24	0.075	0.063			

[a]Pooled variance estimate of t.

[b]Separate variance estimate of t.

(Table 18). Again, seasonal plankton utilization would be the most obvious cause of the change.

Bacteriological Factors of Big Lake and Cyclone Lake. Fecal coliform data for both Big Lake and Cyclone Lake in 1973, statistically resembled those recorded in 1972. In the 1973 sampling season Cyclone Lake maintained very low and relatively homogeneous numbers of bacteria. Big Lake also maintained comparable low concentrations over the season. There were, however, significantly higher bacterial concentrations within Big Lake during July than there were in June (Table 19). No differences were detected between July and August samples. While Big Lake bacterial concentrations were decidedly small, bivariate correlation tests were developed to determine possible causes of the bacterial increase from June to July.

Significant positive correlations were found for precipitation with 4 meter and bottom fecal coliform numbers at Big Lake; the latter correlation being larger (Table 20). Also of significance were the progressively larger with depth, positive correlations of surface, 2 meter, 4 meter and bottom fecal coliform numbers with overall mean concentrations (Table 20). These 2 groups of correlations possibly suggest that bacterial numbers were increased by the disturbance of Big Lake due to strong winds associated with summer thunder storms. Turbulence might have disturbed benthic sediments containing bacterial organisms and resuspended them causing higher organism numbers to be isolated from deeper samples. This was not the case for Cyclone Lake which exhibited

Table 18. Student's t-test results indicating a significant difference between July and August surface nitrate nitrogen concentrations at Cyclone Lake.

		Cyclone Lake Student's t-tests					
Variable	Groups	No. of cases	Mean ppm	Standard Deviation	t value	Degrees of Freedom	Significance Level
Surface nitrate nitrogen	July	12	3.9	1.8	2.15[a]	15	2.13
	August	6	2.6	0.6			

[a]Separate variance estimate of t.

Table 19. Student's t-test results indicating a significant difference between June and July fecal coliform concentrations at Big Lake.

	Big Lake Student's t-test Results						
Variable	Groups	No. of cases	Mean No./100 ml.	Standard Deviation	t value	Degrees of Freedom	Significance Level
Fecal coliform bacteria	June	16	0.7	1.6	2.23[a]	25	2.06
	July	24	4.5	8.3			

[a]Separate variance estimate of t.

Table 20. Bivariate correlation results exhibiting significant correlations of precipitation with 4 meter and bottom fecal coliform concentrations at Big Lake, and significant correlations of surface, 2 meter, 4 meter, and bottom fecal coliform numbers with overall mean concentrations.

	Big Lake Bivariate Correlation Results			
Variables	Groups	Degrees of Freedom	Significance Level	Correlation (r)
Fecal coliform bacteria Precipitation	4 meter Summer	42	.288	.306
Fecal coliform bacteria Precipitation	Bottom Summer	36	.321	.500
Fecal coliform bacteria	Surface Overall	42	.288	.317
	2 meter Overall	43	.286	.332
	4 meter Overall	42	.288	.506
	Bottom Overall	36	.321	.835

no significant correlations of the small concentrations of fecal coliform bacteria with any other measured factor.

Visitor Use of Big Lake and Cyclone Lake. The visitation pattern at Big Lake was unlike that of Cyclone Lake but almost identical to that of Hawley Lake. Visitor numbers increased through June to a maximum in early July, decreased the latter part of July and increased again in August. No significant correlations were identified for Big Lake visitor numbers with other recorded variables. Cyclone Lake visitor use was comparatively low and displayed a pattern of decreasing visitor numbers over the summer season. Fifteen vehicles were counted the first sampling day in June and this number gradually decreased to only 5 vehicles the last sampling day in August. A question was raised as to why this relatively steady reduction in visitation occurred. On-site observation determined the main cause of this decline to be increasingly deteriorated road conditions. Access to Big Lake and Hawley Lake was not much affected by precipitation but the poorly maintained road to Cyclone Lake did occassionally become impassable except by 4-wheel drive vehicles as the summer rains progressed. The road condition at Cyclone Lake is one example of how improper road maintenance negatively affected use of a lake facility. Lower use levels, however, may sometimes be a desired management objective.

North Fork and Sheep's Crossing

Physical Factors of North Fork and Sheep's Crossing. Mean summer water temperatures were significantly cooler at both North Fork and

Sheep's Crossing in 1973 as compared to 1972 (Table 21). Unusually heavy snowpacks persisted in the Mount Baldy area, where the two streams rise, long into summer of 1973. Therefore, these streams were directly influenced by snowmelt for a substantially longer period in 1973. Within the 1973 summer sampling season Sheep's Crossing water temperatures were cooler than North Fork temperatures because of the difference in elevation.

Significant correlations were identified for precipitation with bacteria numbers at both stream reaches. The correlation at Sheep's Crossing was considerably larger than at North Fork. This and other implications are more fully explained in the bacteriological factor section. No other associations were identified for precipitation.

Chemical Factors of North Fork and Sheep's Crossing. Nitrate nitrogen and ortho-phosphate mean season concentrations for North Fork and Sheep's Crossing were not statistically different from their respective recorded concentrations in 1972, nor were mean nutrient levels found to be different between the two reaches in 1973. North Fork exhibited an unusually high nitrate nitrogen reading (6.8 ppm) in early July. Because this high concentration was common to all three stations, as were all other nutrient concentrations at both streams during the sampling season, it was determined that main nutrient inputs were upstream of the sampling area. Natural watershed characteristics and nitrification of ammoniacal wastes from cattle and other animals which graze along the upper reaches of the North Fork might have been primary influences. The Mount Baldy Primitive Area, which has no domestic

Table 21. Student's t-test results indicating significant differences between 1972 and 1973 temperature data for both North Fork and Sheep's Crossing.

Variables	North Fork and Sheep's Crossing Student's t-test Results						
	Groups	No. of cases	Mean	Standard Deviation	t value	Degrees of Freedom	Significance Level
Sheep's Crossing temperatures	1972	27	10.1	2.1	2.54^{a}	27	2.05
	1973	18	7.9	3.2			
North Fork temperatures	1972	21	13.2	2.3	3.18^{b}	37	2.03
	1973	18	10.5	2.9			

[a]Separate variance estimate of t.

[b]Pooled variance estimate of t.

grazing, lies above Sheep's Crossing. This would tend to indicate that natural watershed characteristics were responsible for nutrient concentrations recorded at this stream.

Bacteriological Factors of North Fork and Sheep's Crossing. Statistical comparison of North Fork 1973 data with that of Sheep's Crossing showed no significant dissimilarities. In addition, no differences were identified between mean bacteria numbers from each stream during summer 1973 in relation to 1972 data. Initially, data showed North Fork and Sheep's Crossing to be bacteriologically equivalent. However, interpretation of the data must take into account physical parameter differences (Kunkle and Meiman, 1967).

While data on stream flow were not collected, general on-site observation showed North Fork to have greater flow, depth and width than Sheep's Crossing; average width and depth measurements at North Fork were 7.0 meters and 0.5 meters, respectively. Sheep's Crossing dimensions were approximately one-half those of North Fork. It seems correct to assume (due to dillution effects) North Fork received correspondingly greater fecal contamination to maintain bacteria concentrations statistically similar to those of Sheep's Crossing (Phillips, 1974).

As with nutrients, bacteria numbers at both North Fork and Sheep's Crossing were similar for the three sampling stations within each monitored reach (i.e., there were no cumulative effects of bacterial numbers from upstream stations to downstream stations). This would indicate the majority of contamination came from upstream of both study sites. Cattle, wildlife, recreationists and pets could have acted

as upstream bacteria sources at North Fork. Wildlife were the most obvious bacteria source on the upper Sheep's Crossing watershed.

Significant correlation coefficients determined for precipitation with fecal coliform bacteria at both North Fork (Table 22) and Sheep's Crossing (Table 23) served to emphasize the flushing effect described for other study sites. The larger correlation at Sheep's Crossing indicated bacteria input for this site was more directly related to storm water input. Non-precipitation related bacteria input, such as that added by cattle crossing upper stream locations, might have been responsible for the low rainfall-bacteria correlation at North Fork. Additional influences could have been disturbances of bottom sediments, containing fecal coliforms, by cattle or recreationists and their pets, all of which were seen on a number of occasions wading into the North Fork in, or upstream of, the McCoy's Bridge area. It should be pointed out that fecal coliform bacteria may be added to surface waters not only by direct fecal contamination, but also by primary body contact (Robinton and Mood, 1966; Hanes and Fossa, 1970).

Visitor Use of North Fork and Sheep's Crossing. The recreation areas of North Fork and Sheep's Crossing were comparatively small in relation to the Hawley Lake and Big Lake recreation areas. These spacially limited stream sites made possible, direct counting of all vehicles present at each site on individual sampling days. No statistical difference was identified between North Fork and Sheep's Crossing visitor use. However, North Fork, approximately one-sixth the size of Sheep's Crossing, received a higher concentration and intensity of use

Table 22. Bivariate correlation results exhibiting a significant correlation of fecal coliform concentrations with precipitation at North Fork.

	North Fork Bivariate Correlation Results			
Variables	Groups	Degrees of Freedom	Significance Level	Correlation (r)
Fecal coliform	Summer	13	.514	.545
Precipitation	Summer			

Table 23. Bivariate correlation results exhibiting a significant correlation of fecal coliform concentrations with precipitation at Sheep's Crossing.

	Sheep's Crossing Bivariate Correlation Results			
Variables	Groups	Degrees of Freedom	Significance Level	Correlation (r)
Fecal coliform	Summer	16	.458	.889
Precipitation	Summer			

because of the greater number of visitors per unit area. In addition, North Fork was open to day use and overnight camping while Sheep's Crossing was open to day use only.

Trout Creek

Physical Factors of Trout Creek. The one sampling station on Trout Creek was appended to the research project in 1973. Therefore, a comparison of 1972 data with 1973 data could not be made. Water temperatures of Trout Creek were significantly warmer than those of Sheep's Crossing or North Fork (Table 24). Comparatively low flow, an elevational difference with that of Sheep's Crossing and extended exposure to solar radiation due to the absence of shading vegetation above the Trout Creek sampling station, were the most probable reasons for these temperature differences.

Precipitation data recorded at the Hawley Lake weather station applied to Trout Creek. No significant correlations occurred for rainfall with other physical, chemical or bacteriological data recorded at Trout Creek. The bacterial flushing effect, apparent for North Fork and Sheep's Crossing, was not an important consideration for Trout Creek in 1973 because of the lack of a significant correlation of bacteria with precipitation.

Chemical Factors of Trout Creek. Nitrate nitrogen readings obtained from Trout Creek were not significantly dissimilar from concentrations recorded for the two other stream sites. On the other hand, ortho-phosphate determinations were the highest of the three streams

Table 24. Student's t-test results indicating significant differences between Trout Creek water temperatures and those of North Fork and Sheep's Crossing.

	Trout Creek Student's t-test Results						
Variables	Groups	No. of cases	Mean °C	Standard Deviation	t value	Degrees of Freedom	Significance Level
Trout Creek temperatures	Summer	10	16.8	2.1	5.99[a]	26	2.05
North Fork temperatures	Summer	18	10.5	2.9			
Trout Creek temperatures	Summer	10	16.8	2.1	8.43[a]	26	2.05
Sheep's Crossing temperatures	Summer	18	7.9	3.5			

[a]Pooled variance estimate of t.

investigated (Table 25). Large numbers of crayfish (Orconectes spp.) inhabited the stream area both above and below the sampling station. Throughout the summer, raccoons frequented the station area at night to forage for these crustaceans. The numerous decomposing carapaces, which are high in phosphorus content, in and above the sampling area might have caused greater concentrations of ortho-phosphate to be detected in this shallow, slow moving creek. Large numbers of crayfish are also indicative of nutrient rich conditions. Therefore, a more direct cause might be identified from the fact that Trout Creek was primarily spring fed in the summer months. These underground water sources may absorb phosphorus concentrations through contact with, or the weathering of, phosphatic soil and rocks. However, soil analyses were not within the scope of this project.

Bacteriological Factors of Trout Creek. Trout Creek, with an overall mean concentration of 218 fecal coliform colonies per 100 millilitres, had significantly higher bacteria numbers than North Fork or Sheep's Crossing, as displayed in Table 26. Yet, the relatively small volume of flow at Trout Creek would have caused bacterial contamination to remain more concentrated in relation to North Fork and Sheep's Crossing because of reduced dilution effects. Sign of increased raccoon activity accompanied increased bacterial contamination and led to the assumption that these mammals were the major contributors of fecal bacteria at the Trout Creek sampling station.

Visitor Use of Trout Creek. Hawley Lake campground vehicle numbers were utilized as an index of general visitor use for the Hawley

Table 25. Student's t-test results indicating significant differences between Trout Creek ortho-phosphate concentrations and those of North Fork and Sheep's Crossing.

	Trout Creek Student's t-test Results						
Variables	Groups	No. of cases	Mean ppm	Standard Deviation	t value	Degrees of Freedom	Significance Level
Trout Creek ortho-phosphate	Summer	9	0.207	0.103	2.35[a]	14	2.14
North Fork ortho-phosphate	Summer	7	0.099	0.082			
Trout Creek ortho-phosphate	Summer	7	0.207	0.103	2.92[b]	9	2.26
North Fork ortho-phosphate	Summer	7	0.099	0.051			

[a]Pooled variance estimate of t.

[b]Separate variance estimate of t.

Table 26. Student's t-test results indicating significant differences between Trout Creek fecal coliform concentrations and those of North Fork and Sheep's Crossing.

Variables	Groups	No. of cases	Mean No./100 ml.	Standard Deviation	t value	Degrees of Freedom	Significance Level
		Trout Creek Student's t-test Results					
Trout Creek fecal coliform	Summer	10	218.6	179.6	2.52[a]	9	2.26
North Fork fecal coliform	Summer	18	20.1	22.3			
Trout Creek fecal coliform	Summer	10	218.6	179.6	3.31[a]	9	2.26
Sheep's Crossing fecal coliform	Summer	18	31.1	36.1			

[a]Separate variance estimate of t.

Lake recreation area. No camping, picnicking or other day use sites were near Trout Creek. However, a number of summer homes were located on both sides of the watershed 100 to 150 meters away from the stream channel. Because no meaningful correlations were identified for visitation with bacteria or other variables it was felt the human use near Trout Creek did not have a significant effect on the water quality of that creek in summer of 1973.

SECTION 5

CONCLUSIONS

Four major issues have been the focus of this study: (1) water quality trends associated with recreational use and development, (2) turbidity related water quality factors, (3) nutrient inputs and concentrations associated with water quality, and (4) bacteriological water quality implications. Conclusions pertaining to each of these major issues are presented in separate sections of this chapter.

Water Quality Trends Associated With Recreation Use and Development

Overall comparison of 1973 data with those of 1972, reported by Brickler and Lehman (1973), showed no apparent change in water quality brought about by recreation use and development. This consistent trend should be considered with the fact that visitor use was also consistent over the two seasons. Although no problem trends in water quality were identified it is unwise to project future recreation impacts based only on two years' observation. Therefore, an on-going monitoring program in the nature of this study should be considered as an integral part of the management scheme associated with water-based recreation areas. A monitoring program would serve to facilitate more determinative water quality comparisons over an extended period of time. Consequently, management agencies could better ascertain recreational water quality consistencies, declinations or improvements.

Turbidity Related Water Quality Factors

Secchi disc measurements of relative turbidity, and on-site observation, showed no turbidity problems to be evident for the lakes or streams investigated. A potential erosion hazard was identified, however, associated with trampling and removal of vegetation that began to expose considerable areas of surface soil at some recreation sites. Such a condition promotes the movement of particulate matter into water bodies, resulting in turbidity related problems.

Hawley Lake Turbidity Factors

Investigation of the shoreline of Hawley Lake showed a developing sheet erosion hazard approximate to the west side of the boat dock area. At this location vehicle and pedestrian traffic had removed vegetative cover and compacted soils. Continued use without erosion preventive management action will result in expansion of the abused area.

Big Lake Turbidity Factors

Although Big Lake showed no greatly developed erosion problems, heavy pedestrian traffic and fishing activity adjacent to the boat dock and boat ramp areas had caused trampling and removal of shoreline vegetation. It is common for water-based recreation sites, even those with low numbers of users per unit area, to receive intensive use on immediate shorelines due to facility locations and the natural attraction of visitors to the water's edge. Protective management practices and proper planning of facility locations can reduce this type of impacting.

Cyclone Lake Turbidity Factors

An appreciably eroded area was located at Cyclone Lake along both sides of the graded lake access road where it enters the site. This road parallels the north shore 2 to 5 meters above the lake surface and cuts into the side of a 60 to 80 percent slope. Fishermen often descended this steep slope, uprooting limited vegetation and disturbing soil and rock materials. This situation, unchecked, would be conducive to gully and slump erosion that would have negative effects on both the access road and the lake environment.

North Fork, Sheep's Crossing and Trout Creek Turbidity Factors

The popularity, and topographically limited size of the North Fork recreation area combined to create an intensively used site. This resulted in numerous tire ruts, reduced vegetative cover and soil compaction. These conditions, if allowed to continue, will rapidly deteriorate this unusual recreation site and may significantly increase stream turbidity.

The shorelines of Sheep's Crossing and Trout Creek were not perceptably effected by erosion or denudation. However, prior to the 1972 recreation season the U. S. Forest Service set restrictions on vehicle access to the Sheep's Crossing shoreline as a result of severe impacting. The rest period, 1972-1973, had an appreciative positive effect.

Nutrient Inputs and Concentrations Associated With Water Quality

Nutrient concentrations in a water body of 0.01 ppm inorganic phosphorus, and 0.30 ppm of inorganic nitrogen (which include ortho-phosphate and nitrate nitrogen, respectively) are, at the beginning of the active aquatic growing season, ample quantities to support nuisance algal blooms (Sawyer, 1952 and 1954). Consequently, the water bodies studied in this project were well enriched with nutrient concentrations 20 to 30 times those described above. This would indicate eutrophication processes would not be restricted in these waters because of insufficient nutrient availability.

Although colorimetry, the technique used for chemical analysis, is a recognized procedure it is considered to be somewhat variable and is principally used where a very few established determinations have been made (Sawyer and McCarty, 1967). This was the case for the waters in the study. Nonetheless, data show moderately eutrophic conditions were prevalent and analyses indicated nutrients were from natural rather than man related sources. Those natural sources approximate to the recreation waters included nutrients in livestock waste, precipitation, runoff, bottom sediments, decomposing plankton, parent material and soils. Nitrates and phosphates contributed by transient waterfowl, falling tree leaves and ground water may also be important additions to recreation site nutrient budgets.

Bacteriological Water Quality Implications

Hawley Lake Bacteria Implications

Of the 3 lakes investigated Hawley Lake showed the highest overall season mean of 24 fecal coliform colonies per 100 millilitres. The vast majority of fecal organism numbers responsible for this condition were obtained from surface waters at Hawley Lake on the sampling days of July 11 and 13. This particular period of relatively high bacteria counts corresponded with intensive summer thunderstorms, the first of which occurred on July 11.

As explained by Geldreich et al. (1968) storm water is the major intermittent source of bacterial pollution that enters waterways. After precipitation comes in contact with the earth, contaminants are added from various environmental sources. At the beginning of a rainfall event following a dry period of several weeks or more, bacterial concentrations are relatively high in surface runoff. As the rain period continues the density of pollution decreases to low levels as a result of dilution.

At Hawley Lake, fecal matter was deposited on the watershed over the long dry period of June and early July. Summer thunderstorms began the second week of July and their initial runoff flushed the watershed carrying increased numbers of fecal bacteria into the lake. Consequently, higher bacteria concentrations were recorded with individual sample counts as high as 800 colonies per 100 millilitres. Shortly following the first thunderstorm a post flush decrease was observed resulting in low bacteria concentrations of only a few organisms per 100 millilitres

comparable to those recorded in June. Heavy summer rainfall continued intermittently through the latter portion of the season. No additional bacterial flushing effects were evident, however, due to dilution influences of the added precipitation.

One obvious question arises as to why data showed Hawley Lake to have been significantly influenced by a bacterial flushing effect while Big Lake, with a similar precipitation pattern, and Cyclone Lake, with identical rainfall, were not correspondingly influenced. There are two possible answers: (1) that Big Lake and Cyclone Lake had comparable bacterial flushing effects which were not detected because their less frequent sampling schedules did not coincide with flushing periods, or (2) that Hawley Lake did, indeed, receive greater fecal contamination because the intensively used watershed received more contamination than the Big Lake or Cyclone Lake watersheds and correspondingly contributed significantly higher fecal coliform concentrations to the lake through the flushing effect. Lack of substantial results regarding this issue prohibited the selection of a definite conclusion. However, the possible conclusion that more intensive use and development was accompanied by a greater concentration of fecal contamination on the Hawley Lake watershed was made more credible by a separate result from the analyses. The more heavily used and developed portion of Hawley Lake, itself, contributed significantly greater fecal contaimination to the lake than did the area with little or no use and development by means of stormwater runoff.

Hawley Lake was the most intensively used and developed lake of the three studied. The difference from Cyclone Lake was easily

identified as this small impoundment received relatively little use and was virtually lacking in development. A number of superficial comparisons were necessarily made to determine use and development differences between Hawley Lake and Big Lake: (1) Hawley Lake was approximately one-half the size of Big Lake but received comparable use in terms of numbers of visitors on the site, (2) one residential cabin was located at Big Lake 150 meters from shore; Hawley Lake had more than 450 summer homes on its more spacially limited watershed, some of which were no further than 30 meters from shore, (3) Big Lake had 200 designated campsites, the closest to shore being 150 to 200 meters distant; Hawley Lake had a camping area with no designated sites which accommodated more than 100 camping groups, a number of whom located themselves adjacent to the shoreline, and (4) recreation use at Big Lake included camping, fishing, picnicking, boating and sightseeing; Hawley Lake provided these same experiences in addition to summer home vacationing, mobile home parking, bungalow rentals and horseback riding. Evaluation of these comparisons made dissimilarities between Hawley Lake and Big Lake readily apparent.

Fecal Coliform to Fecal Streptococci Ratios

The fecal coliform to fecal streptococci ratios of Table 7 (Section 3) were relatively insignificant in terms of identifying a definite bacteria source. They did tend to indicate the majority of samples applied to ratio analyses displayed results implicating non-human origin. Hence, animals on the site such as livestock, pets and wildlife were probably primary bacterial sources. However, a number of distinctly human fecal contamination sources were observed at various

times on the Hawley Lake watershed. These were in the boat dock area and were in the form of: (1) several soiled, disposable diapers, (2) soiled toilet tissue transported by wind from underneath a full, earthen pit privy, (3) fecal matter unearthed by dogs from an abandoned privy pit, and (4) one occasion of overflow from the sewage pump house (30 meters from the lake) that spread over 200 square foot area of soil and vegetation in direct route to the lake. These observations brought about a conclusion that some of the contamination detected in this lake area was at least from mixed sources.

Big Lake and Cyclone Lake
Bacteria Implications

Minimal fecal contamination was recorded for Big Lake and Cyclone Lake, each having overall means of 2 to 3 fecal coliform colonies per 100 millilitres. Big Lake was 15 times the size of Cyclone Lake and received use, in terms of numbers of visitors, comparable to that of Hawley Lake. Cyclone Lake had no more than 35 visitors on its adjacent watershed during any one sampling period. One might initially infer that an impoundment such as Big Lake with much greater use than Cyclone Lake must accordantly receive and exhibit greater fecal contamination. However, the high number of users at Big Lake were distributed over a much larger area than at Cyclone Lake or Hawley Lake. In addition, relatively few pets were seen near shore areas at Big Lake, and the several privies on the site were of sealed vault design and well maintained. The large majority of sanitation developments at Big Lake were equipped with flush facilities, served by a small sewage treatment

installation outside the immediate watershed. This installation did not release effluent back to the lake.

Small groups of cattle occasionally grazed the east and north shore areas of Big Lake but, for the most part, were removed from the shore areas. The large volume and greater mixing action of Big Lake assisted the natural absorption of minor contamination that might have occurred from cattle and other possible sources.

North Fork and Sheep's Crossing
Bacteria Implications

North Fork and Sheep's Crossing data were not found to be statistically different from one another as each had an overall mean fecal coliform concentration of 20 to 30 colonies per 100 millilitres. However, considering North Fork had greater flow than Sheep's Crossing, it had to receive a correspondingly larger amount of fecal contamination to maintain statistically similar concentrations in a more diluted environment. Data analyses and evaluation indicated the most probable source of fecal contamination for Sheep's Crossing was fecal matter of upstream wildlife from which bacterial organisms entered the stream channel through the rainfall flushing effect. Fecal contamination at North Fork was evidently caused by upstream sources which were known to be above McCoy's Bridge. These included: (1) visitors and pets at several recreation sites located along the North Fork, (2) cattle which grazed the upper North Fork watershed extensively over the summer season, and (3) various wildlife species.

Trout Creek Bacteria Implications

Trout Creek exhibited an overall mean fecal coliform concentration of 218 colonies per 100 millilitres. This was considerably higher than the other 2 stream sites. Bacteria were more concentrated in Trout Creek at least partially due to its smaller environmental volume. Flow at this stream site was considerably less than that of Sheep's Crossing. The lack of a flushing effect association with monitored fecal coliform concentrations suggested that a more direct fecal contaminant source was involved. Raccoons foraged for crayfish at the sampling station almost nightly and were the most obvious source of fecal coliform bacteria at Trout Creek.

Relative Fecal Bacteria Standards

Although this study was not a public health oriented investigation it is necessary to refer to health considerations in association with bacteriological quality standards for recreation waters. The access of fecal pollution to water may add a variety of intestinal pathogens at any time, and, periodically, enteric pathogenic bacteria probably will be present. The presence and density of pathogens in human and other warm blooded animal feces are of much lower magnitude, however, than those of fecal coliform bacteria. It is the probability of the presence of pathogens in water containing particular densities of indicator organisms which is the basis for fecal coliform standards.

Approximately 25 states and territories have adopted fecal coliform standards for primary contact recreation waters. These range from 1,000 colonies per 100 millilitres for Mississippi, Tennessee and

Georgia to 70 colonies per 100 millilitres for the Virgin Islands (U. S. Environmental Protection Agency, 1972). Secondary contact waters, which include those exmained here, generally have less stringent standards that are even more variable than those for primary contact. These inconsistencies reflect the uncertainties various health agencies have concerning pathogen probabilities in relation to fecal coliform concentrations. Field data from numerous freshwater and estaurine pollution studies indicate a sharp increase in the frequency of the common pathogen Salmonella when fecal coliform densities are above 200 organisms per 100 millilitres (Geldreich, 1969). The National Technical Advisory Committee (quoted by Geldreich, 1969, p. 118) recommended that for primary contact recreation (i.e., bathing waters) "the fecal coliform content...shall not exceed a log mean of 200/100 ml., nor shall more than 10 percent of the total samples during any thirty day period exceed 400/100 ml." This standard is now gaining wide acceptance.

The Water Quality Council (1968) of the state of Arizona adopted a primary contact fecal bacteria standard quite similar to the one mentioned above with the exception that standards are described in terms of geometric rather than log means. Arizona also has a bacteria quality standard for waters other than primary contact which states the fecal coliform value "shall not exceed a geometric mean of 1,000/100 ml., nor shall more than 10 percent of the samples during any 30 day period exceed 2,000/100 ml." (p. 45).

Analyses of the data obtained in this investigation determined none of the waters investigated exceeded Arizona's bacterial standards for secondary contact recreation. Only the Trout Creek sampling station

exhibited bacterial concentrations which would have exceeded standards established for water used in primary contact recreation.

Overall Conclusions

Though no major pollution problems were identified for the lakes and streams studied the potential for major problems does exist. First, apparent association of intensive recreational use and development with significantly higher fecal coliform bacteria concentrations points out that expected future growth in water-based recreation may well increase bacterial pollution of White Mountain recreation waters; and secondly, improper management and misuse of immediate shoreline areas may significantly increase denudation and erosion--turbidity problems. This need not be the case, however, should recreation land managers in the White Mountains maintain a sensitivity toward possible pollution problems, remain aware of current research developments and perpetuate responsible recreation resource planning.

SECTION 6

GUIDELINES OF CONTROL

This study investigated a broad range of environmental and recreational use factors that are characteristic of the parameters of recreation waters and associated watersheds. Because of the diversity of recreation use patterns and areas guidelines of control must consider the broad range of possible conditions under which pollution and other impacting may occur by examining, first, general and then specific problem situations.

The quality of recreation lakes and streams is determined by natural and man related conditions affecting those waters and the watersheds on which they are located. Guidelines functioning to limit deterioration of water quality should first apply to recreational use of the land and water,and second to the physical, chemical and bacteriological character of the land and water. Each recreational activity demands individual consideration based on the activity's potential to deteriorate land or water conditions. Each land and water environment must be closely studied to determine its capacity to tolerate specific types and intensities of recreation use. Guidelines of control given here are necessarily presented as general management considerations. Specific recreation areas and activities have individual problems which might require management action that would not be universally applicable. Hence, guidelines which guard against every possible negative impact

from public use of water-based recreation areas might seriously limit relaxes use and enjoyment of an individual water area.

General Water-based Recreation Management Considerations

The following are presented as broad precautionary measures dealing with conditions caused by the overuse or improper use of water-based recreation areas:

1. A basic philosophy of purpose, use and development should be established. It should take into consideration the environmental character and possible and expected uses of a recreation water and its watershed.

2. Criteria should be established for determining the capacity of a recreation site to withstand the impact of recreation use and associated pollution.

   Based on these criteria and the philosophy of use, a plan of land-use controls should be drawn which would aid in facilitating an orderly pattern of development and use.

3. Appropriate soil conservation programs should be initiated to protect watersheds, shorelines and water quality.

   During periods when considerable land development occurs along lake or stream perimeters, efforts should be made to limit disturbance of soil and natural vegetation as surface water run-off, accelerated by loss of protective cover, may increase particulate matter entering receiving waters.

4. Intensive development programs should be dispersed over time instead of being permitted to occur simultaneously.

Where adequate sewage systems or facilities have not yet been established, human fecal contamination may exist in conjunction with new development sites. Contamination may increase with the intensity of use and congestion of vacation homes and other developments. During the early years of development, fecal contamination factors may be much more significant if such conditions occur extensively and in critical areas of a watershed especially if developments are allowed to concentrate in limited areas.

5. Lake development and recreational use areas should be located with respect to the tolerance of lakeshore lands and waters to absorb bacterial pollutants associated with these uses.

For example, in shallow area coves where movement of water is restricted, circulation of fresh water may be limited during periods of summer stagnation. Runoff from lands surrounding these coves may carry bacterial waste into calm areas causing concentration of pollution. Conversely, runoff from points of land which extend out into a lake is usually dispersed around the border of the point and tends not to concentrate pollution. Waters surrounding points of land often seem to be more subject to movement and to mixing with water from nearby deep areas.

Many factors of watershed topography, soils, length and degree of slope, and vegetational cover affect the tolerance of land for various kinds of recreational use. Those uses should be planned after careful consideration of land-use capabilities.

6. All direct bacterial and chemical pollution from garbage and refuse dumps, improperly constructed or maintained pit privies, unsealed marine toilets on boats, livestock, and other related sources should be eliminated.
7. Close compliance with local, state and federal health and water regulations should be maintained to preclude pollution from recreational use and development.
8. Programs of regular and systematic water analyses should be established to identify polluting situations or significant changes in bacterial, chemical or physical aspects of water quality.

Fort Apache Indian Reservation Specific Management Considerations

Hawley Lake, Cyclone Lake, North Fork and Trout Creek are located on Fort Apache Indian Reservation and are under the management jurisdiction of the White Mountain Recreation Enterprise. This agency has established regulations concerning recreation use, some of which were irregularly enforced in 1973. Management considerations presented in this section are associated with on-site observation of potential recreational use and development problems that may relate to already established regulations. The scope of the research was not designed to measure impacts of the observed problems. The specific effects of each on water quality would require further study.

The following are offered to direct management attention toward potential problems at individual sites.

Hawley Lake

1. Campground users at Hawley Lake should be restricted from camping within the immediate shore area to reduce impacts on the shoreline and increase the distance wastes must travel before reaching the lake.
2. Designated roadways and campsites at Hawley Lake should be established in the camping area to prevent unrestricted vehicle access throughout the campground and also prevent the indiscriminate placement of campsites. Further, graded roadways should be covered with gravel or cinder materials to reduce erosion hazard.
3. Parking on the barren slope used as a public boat ramp near the boat dock at Hawley Lake should be eliminated and a surfaced ramp developed to meet the limited needs of the site. Remaining bare areas should be revegetated to reduce erosion.
4. All vehicle access to the Hawley Lake shoreline should be prohibited except at the location of the public ramp. This would eliminate numerous scattered erosion and compaction problems.
5. Earthen pit privies are inadequate sanitation facilities for this recreation site and should be removed and replaced by well maintained sealed vault toilets.
6. Abandoned privy pits should be filled in such a way as to prevent animals from unearthing wastes, but also permit revegetation to occur.

7. Pets on the watershed should be restrained at all times and owners should be required to properly dispose of pet feces in a waste facility.
8. Septic tanks and leech fields installed on the watershed in the future should be distant enough from the lake shore to prevent underground flow from these sanitation installations from affecting the water quality of the lake.
9. All home owners should be made well aware that their activities and facilities may directly or indirectly affect the water quality of the lake: preventive management guidelines should be distributed to each.
10. The sewage pump house at Hawley Lake should be relocated in an area where accidental overflow would not drain directly into the lake. If relocation is not feasible a check dam installation should be developed to contain sewage overflow. Preventive maintenance is important for this facility.
11. A waste disposal facility should be installed in the Hawley Lake campground area to receive wastes from holding tanks in recreational vehicles.
12. The disposal of all types of waste water from recreational vehicles anywhere but in a designated waste receiving facility should be prohibited.
13. Discarding of disposable diapers anywhere but in a waste facility should be prohibited.
14. The Hawley Lake recreation area should be fenced to prevent cattle from entering the immediate watershed. This would reduce

bacterial contamination of the watershed and also reduce trampling of the shoreline.

15. Established littering restrictions should be more strongly enforced.

Cyclone Lake

1. Visitors should be prohibited from using the steep slope adjacent to the north shore access road as a route to the lake. A revegetation program should be instigated for this denuded and eroded slope.
2. Larger culverts should be installed where the access road crosses Sand Creek and Lame Deer Creek that would be capable of withstanding high spring runoff.
3. The roadway along the Cyclone Lake shoreline should be plainly designated and covered with a surfacing material such as gravel or cinders to help prevent erosion.
4. One specific area should be designated for the launching of boats at Cyclone Lake rather than permitting visitors to randomly select their own launching sites.
5. In the southeast shore area of Cyclone Lake are two earthen pit privies that should be removed and replaced by well maintained sealed vault facilities. In addition, sealed vault toilets should be distributed conveniently around the shore area.
6. Pets should be restrained at all times and owners should be required to properly dispose of their pet's wastes in a waste facility.

7. Disposal of all types of waste water from recreational vehicles should be prohibited at this recreation site.

North Fork

1. This small and relatively fragile recreation site should be restricted to day use only to prevent continued, extensive impacting.
2. Log curbs should be installed at North Fork to prevent visitors from driving off designated roadways or parking areas. In addition, these roadways and parking areas should be surfaced with gravel or cinder materials to minimize erosion hazard.
3. Fording of the North Fork of the White River at the North Fork recreation site, by any type of vehicle, should be prohibited to reduce physical impacting on the stream channel.
4. Two earthen pit privies on the north bank area should be removed and replaced by well maintained sealed vault toilets. These facilities should be distant enough from the stream and upslope of the flood channel so as to prevent underground seepage from possibly entering the stream. Two additional vault toilets should be installed on the south bank area under the same restrictions.
5. Pets at North Fork should be restrained at all times and owners should be required to properly dispose of their pet's feces in a waste facility.
6. Disposal of all types of waste water from recreational vehicles at North Fork should be prohibited.

7. Established littering restrictions should be more strongly enforced.

Trout Creek

1. More quantitative nutrient analyses might be initiated to determine the sources of relatively high ortho-phosphate concentrations recorded for this stream. Such analyses should include: (a) identification of all possible phosphate sources, and (b) the development of tests to determine proportionate inputs from each source. If an unnatural problem source is identified, steps to reduce input might be taken if they would not cause significantly negative effects on the biological character of Trout Creek.

Apache National Forest
Specific Management Considerations

Big Lake and Sheep's Crossing are located on Apache National Forest and are under the management jurisdiction of the U. S. Forest Service. Effective enforcement of recreation use regulations was administered by the U. S. Forest Service at these recreation sites. However, several potential management problems were discerned through on-site observation at Big Lake and Sheep's Crossing. The following management considerations are in response to observed problems; as with those considerations developed for Fort Apache Indian Reservation the specific effects of each potential problem on water quality would require additional study.

Big Lake

1. Vehicle access on the west shore of Big Lake should be better controlled to prevent driving and parking on the immediate shoreline and thus reduce denudation and erosion hazard.
2. All pet owners should be required to dispose of their pet's feces in a waste facility.
3. The disposal of all types of waste water from recreational vehicles anywhere but in a designated waste facility should be prohibited.
4. Fencing should be installed to prevent cattle from grazing on or adjacent to the Big Lake shore areas. This would reduce bacterial contamination and trampling of the immediate watershed.
5. The unsightly and unsafe garbage incinerator adjacent to the boat dock at Big Lake should be removed from the recreation site.

Sheep's Crossing

1. The much used parking site for the Mount Baldy Primitive Area trailhead located on the Sheep's Crossing site should have perimeters defined by the placement of log curbs and should be surfaced with gravel or cinder materials to reduce erosion hazard.
2. The access road from the Sheep's Crossing bridge area to the Primitive Area trailhead should be better maintained to reduce driving and erosion hazards.

3. As no sanitation facilities were present on the Sheep's Crossing recreation site, sealed vault toilets should be installed near the Primitive ARea trailhead and near the road bridge.
4. Pets should be restrained at all times and owners should be required to properly dispose of their pet's feces in a waste facility.
5. Disposal of all types of waste water from recreational vehicles should be prohibited at this recreation site.
6. Fencing around the recreation site should be maintained to prevent cattle from entering the Sheep's Crossing recreation area, increasing nutrient and bacterial concentrations.

BIBLIOGRAPHY

Adams, R. and E. Geiser. 1970. Preliminary report and recommendations for the Summerhaven, Arizona sewerage system. U. S. Forest Serv., Coronado National Forest, Arizona, unpublished report. 36 p.

American Association of Soap and Glycerin Producers. 1958. Determination of orthophosphate, hydrolyzable phosphate, and total phosphate in surface waters. J. Amer. Water Works Assoc. 50: 1563-1574.

American Public Health Association. 1971. Standard Methods for the Examination of Water and Waste Water. 13th Ed., Washington, D.C. 874 p.

Armstrong, R. Dec. 1974. Apache National Forest Recreation Officer, Springerville, Arizona, personal communication.

Badaracco, R. J. 1971. Learning in the Pepsi generation. College of Forestry and Natural Resources, Colorado State University, Fort Collins, unpublished paper. 7 p.

Barbaro, R. D., B. J. Caroll, L. B. Tebo, and L. C. Waters. 1969. Bacteriological water quality of several recreational areas in the Ross Barnett Reservoir. J. Water Poll. Control Fed. 41: 1330-1339.

Blalock, H. M. 1972. Social Statistics. McGraw-Hill Book Co., New York. 583 p.

Breed, R. S., E. G. Murray, and N. R. Smith. 1957. Bergey's Manual of Determinative Bacteriology. Williams and Wikins Co., Baltimore. 1094 p.

Brickler, S. K. and G. S. Lehman. 1972. Procedures for detecting the impact of recreation use and development on water quality of recreation reservoirs using established techniques. Department of Watershed Management, The University of Arizona, Tucson, unpublished research proposal. 7 p.

Brickler, S. K. and G. S. Lehman. 1973. Impact of recreation use on water quality in the White Mountains of Arizona. Cooperative Agreement 16-28-CA, U. S. Forest Serv., Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, unpublished report. 19 p.

Brock, T. D. 1970. Biology of Microorganisms. Prentice-Hall Inc., Englewood Cliffs, New Jersey. 737 p.

Bureau of Outdoor Recreation. 1967. Outdoor Recreation Trends. U. S. Govt. Print. Off., Washington, D.C. 24 p.

Bureau of Outdoor Recreation. 1973. Outdoor Recreation, A Legacy for America. U. S. Govt. Print. Off., Washington, D. C. 89 p.

Carlson, R. E. 1971. The recreational uses of water. Department of Recreation and Park Administration, Indiana University, Bloomington, unpublished paper. 19 p.

Dambach, C. A. 1956. Recreational use of impounding reservoirs. J. Amer. Water Works Assoc. 48:517-521.

Doudroff, B. and M. Katz. 1950. Critical review of literature on the toxicity of industrial wastes and their components to fish. Sewage and Industrial Wastes 22:1432-1458.

Federal Interagency Group for the Southwest Interagency Committee. 1970a. Lower Colorado Region Comprehensive Framework Study, Appendix VI. Land Resources and Use. Preliminary field draft, Lower Colorado Region. 142 p.

Federal Interagency Group for the Southwest Interagency Committee. 1970b. Lower Colorado Region Comprehensive Framework Study, Appendix XV. Water Quality, Pollution Control and Health Factors. Preliminary field draft, Lower Colorado Region. 144 p.

Geldreich, E. E. 1966. Sanitary Significance of Fecal Coliforms in the Environment. Fed. Water Poll. Control Admin., Washington, D.C. 122 p.

Geldreich, E. E. 1969. Applying bacteriological parameters to recreational water quality. J. Amer. Water Works Assoc. 62:113-120.

Geldreich, E. E., L. D. Best, B. A. Kenner, and D. J. Van Donsel. 1968. The bacteriological aspects of storm-water pollution. J. Water Poll. Control Fed. 40:1861-1872.

Geldreich, E. E., R. H. Bordner, C. B. Huff, H. F. Clark, and P. W. Kabler. 1962. Type distribution of coliform bacteria in the feces of warm-blooded animals. J. Water Poll. Control Fed. 34:295-301.

Geldreich, E. E., C. B. Huff, R. H. Bordner, P. W. Kabler, and H. F. Clark. 1962. The fecal coli-aerogenes flora of soils from various geographical areas. J. Appl. Bacter. 25:87-93.

Geldreich, E. E. and B. A. Kenner. 1969. Concepts of fecal streptococci in stream pollution. J. Water Poll. Control Fed. 41: 336-352.

Hach Chemical Corporation. 1971. Methods Manual. Hach Chemical Corp., Ames, Iowa. 67 p.

Hanes, N. B. and A. J. Fossa. 1970. A qualitative analysis of the effects of bathers in recreational water quality. Advances In Water Poll. Res. 12:HA9/1-HA9/9.

Hutchinson, G. E. 1957. A Treatise on Limnology, Volume I. John Wiley and Sons, Inc., New York. 1115 p.

Ingram, W. M. and G. W. Prescott. 1954. Toxic freshwater algae. American Midland Naturalist 52:75-87.

Jones, G. H. 1968. Water as a recreation resource. Environmental Resources Branch, U. S. Army Corps of Engineers, Southwestern Division, Dallas, Texas, unpublished report. 16 p.

Kenner, B. A., H. F. Clark, and P. W. Kabler. 1961. Fecal streptococci I. Cultivation and enumeration of streptococci in surface waters. Appl. Microbio. 9:15-20.

Kittrell, F. W. 1969. A Practical Guide to Water Quality Studies of Streams. Fed. Water Poll. Control Admin., Washington, D. C. 135 p.

Kunkle, S. H. and J. R. Meiman. 1967. Water quality of mountain watersheds. Hydrologic paper 21, Colorado State University, Fort Collins. 53 p.

Mackenthun, K. N. 1968. The phosphorus problem. J. Amer. Water Works Assoc. 60:1047-1054.

Mackenthun, K. N. and W. M. Ingram. 1964. Limnological Aspects of Recreation Lakes. U. S. Govt. Print. Off., Washington, D. C. 176 p.

Mahloch, J. L. 1974. Comparative analysis of modeling techniques for coliform organisms in streams. Appl. Microbio. 27:340-345.

McFeeters, G. A. and D. G. Stuart. 1972. Survival of coliform bacteria in natural waters: field and laboratory studies with membrane filter chambers. Appl. Microbio. 24:805-811.

Millipore Corporation. 1973. Biological Analysis of Water and Waste Water. Millipore Corp., Bedford, Massachusetts. 84 p.

Minckley, W. L. 1972. A survey of selected physico-chemical and biologic parameters of Aravaipa Creek, Arizona. Department of Zoology, Arizona State University, Tempe, unpublished report. 32 p.

Nie, N. H., D. H. Bent, and C. H. Hull. 1970. Statistical Package for the Social Sciences. McGraw-Hill Book Co., New York. 343 p.

Nie, N. H., D. H. Bent, and C. H. Hull. 1973. Statistical Package for the Social Sciences Update, Manual Version 5.5. Vogelback Computing Center, Northwestern University, Evanston, Illinois. 95 p.

Outdoor Recreation Resources Review Commission. 1962a. National Recreation Survey. U. S. Govt. Print. Off., Washington, D. C. 394 p.

Outdoor Recreation Resources Review Commission. 1962b. Outdoor Recreation for America, Report to the President and Congress. U. S. Govt. Print. Off., Washington, D. C. 246 p.

Phillips, R. A. Dec. 1974. Professor, Department of Civil Engineering and Mechanics, University of Arizona, Tucson, personal communication.

Public Law 91-190. 1970. National Environmental Policy Act of 1969. 91st Congress, S.1075. 5 p.

Quimby, B. 1974. Popular vacation area ready for annual crowd. Feature article, Tucson Daily Citizen, May 17.

Rademacher, J. M. 1968. Effects of multiple uses of watersheds on water quality. J. Amer. Water Works Assoc. 60:1247-1254.

Riehl, M. L. 1956. Discussion--recreational use of impounding reservoirs. J. Amer. Water Works Assoc. 48:521-524.

Robinton, E. D. and E. W. Mood. 1966. A quantitative and qualitative appraisal of microbial pollution of water by swimmers. J. Hygene 64:489-499.

Roseberry, D. A. 1964. Relationship of recreational use to bacterial densities of Forrest Lake. J. Amer. Water Works Assoc. 56: 43-59.

Ruttner, F. 1963. Fundamentals of Limnology. University of Toronto Press, Toronto. 265 p.

Sawyer, C. N. 1952. Some new aspects of phosphates in relation to lake fertilation. Sewage and Industrial Wastes 24:317-325.

Sawyer, C. N. 1954. Factors involved in disposal of sewage effluents to lakes. Sewage and Industrial Wastes 26:317-325.

Sawyer, C. N. and P. L. McCarty. 1967. Chemistry for Sanitary Engineers. McGraw-Hill Book Co., New York. 518 p.

Schwoerbel, J. 1970. Methods of Hydrobiology Freshwater Biology. Pergamon Press, London. 200 p.

Sewage disposal now pressing problem in Arizona Highlands. 1970. Arizona Farmer-Ranchman 19:12.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods. Iowa State University Press, Ames, Iowa. 593 p.

Steel, R. G. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., New York. 481 p.

Stull, E. A. Dec. 1974. Assistant Professor of Limnology, Department of Biological Sciences, University of Arizona, Tucson, personal communication.

U. S. Department of Agriculture. 1968. Soil Survey, Fort Apache Indian Reservation, Arizona. U. S. Soil Conservation Serv., unpublished manuscript. p. 75-86.

U. S. Environmental Protection Agency. 1972. Water Quality Criteria Data Book, Volume 4. Publication Branch (Water), Research Information Division, R & M, U. S. Envir. Prot. Agency, Washington, D. C. 257 p.

Van Donsel, D. J. and E. E. Geldreich. 1971. Relationships of Salmonella to fecal coliforms in bottom sediments. Water Research 5:1079-1087.

Van Donsel, D. J. and E. E. Geldreich. 1972. Bacterial bottom sampler for water sediments. J. Guarraia and R. Ballentine (eds.). The Aquatic Environment, Symposium On Microbiological Transformations and Water Management Implications. U. S. Envir. Prot. Agency, Office of Water Programs, Washington, D. C. p. 237-244.

Van Donsel, D. J., E. E. Geldreich, and N. A. Clarke. 1967. Seasonal variations in survival of indicator bacteria and their contribution to stormwater pollution. Appl. Microbio. 15:1362-1370.

Water Quality Control Council. 1968. Water Quality Standards for Surface Waters in Arizona. Arizona State Department of Public Health, Phoenix. 127 p.

Water Quality Division Committee on Nutrients in Water. 1970. Chemistry of nitrogen and phosphorus in water. J. Amer. Water Works Assoc. 62:127-140.

Wilson, J. 1959. The effects of erosion, silt and other inert materials on aquatic life. Trans. Second Seminar on Biol. Probs. and Water Poll. Tech. Report No. W60-3, U. S. Pub. Health Serv., Washington, D. C. p. 269-271.

Worms, A. J. and S. K. Brickler. 1967. Effects of recreation use and development on water quality. Resources development series 12, Agri. and Home Ec. Coop. Exten. Serv., University of Kentucky, Lexington. 9 p.